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Project Report

PA-229-13
(RSP)

Data Reduction Program Documentation ALTPOD

(Effective: August 1971)

C. R. Berndtson
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19769

26 August 1971

Prepared for the Advanced Research Projects Agency, the Department of the Army, and the Department of the Air Force under Electronic Systems Division Contract F19628-70-C-0230 by

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts

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LINCOLN LABORATORY

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DATA REDUCTION PROGRAM DOCUMENTATION
ALTPOD
(EFFECTIVE: AUGUST 1971)

10

C. R. BERNDTSON

Group 92

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Philco-Ford Corporation

Editors

12 58 p.

14

9 PROJECT REPORT PA-229-13
(Re-entry Systems Program)

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L. G. Hanscom Field
Bedford, Mass, 01730

LEXINGTON MASSACHUSETTS

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FOREWORD

This is the thirteenth report in the Data Reduction Program Documentation series. It is dated according to the date of completion of the documentation. No implication is made that this program will not subsequently be modified, amended, or superseded; on the contrary, the history of radar data processing is one of continuous evolution of techniques, and it is unrealistic to assume that steady-state has been reached.

The preparation of reports in this series is under the Editorship of Charles R. Berndtson of Lincoln, and of D. Nessman and R. French of Philco-Ford Corporation. Inquiries, suggestions, corrections, criticisms, and requests for additional copies should be directed to C. R. Berndtson.

The principal contributor to this report was G. M. Sheinfeld (Philco-Ford). Due to the intricate, evolutionary manner in which the programs came into being, the editors regret that it is in general impossible to give due credit to all -- mathematicians or radar analysts or programmers -- who contributed to the definition and writing of the programs.

Alan A. Grometstein

Alan A. Grometstein

CONTENTS

CONTENTS (cont'd)

COMMON SYMBOLS AND ABBREVIATIONS

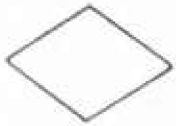
(The units given for certain quantities are the units commonly used for those quantities, unless otherwise noted.)

ADT	ALCOR Data Tape
ALCOR	ARPA-Lincoln C-band Observables Radar
ALTAIR	ARPA Long-Range Tracking and Instrumentation Radar
Alt	Altitude (km)
APS	Average Pulse Shape
ARS	ALTAIR Recording System
ARTP	ALTAIR Real Time Program
ATC	Angle Track Console
Avg	Average, Averaging
Az	Azimuth (deg)
c	Speed of Light
CADJ	Adjusted Calibration Constant (db)
C-band	ALCOR frequency, 5664 MHz (NB) and 5667 MHz (WB)
DBLT	Wide Band Pulse Doublet
DCO	Designations and Communications Operator
El	Elevation (deg)
EOF	End of File
GMT	Greenwich Mean Time
h	Hours
Hz	Hertz
IF	Intermediate Frequency
in	Inches
IRV	Inter-Range Vector
LC	Left Circular Polarization
lsb	Least Significant Bit
min	Minutes
NB	Narrow Band
NRTPOD	Non-real Time Precision Orbit Determination Program

POD	Project PRESS Operation and Data Summary Report
Phase	Presented in deg
PRF	Pulse Repetition Frequency (pps)
PRI	Pulse Repetition Interval (s)
pps	Pulses per second
pts	Points
R	Range (km)
$\dot{R}$	Range Rate (km/s)
rad	Radians
RC	Right Circular Polarization
RCS	Radar Cross Section (dbsm)
RF	Radio Frequency
RGC	Receiver Gain Control
RTC	Range Track Console
s	Seconds
SD_w	Standard Deviation of Wake Velocity
SDBLT	Wide Band Slaved Pulse Doublet
S/N	Signal-to-noise Ratio
T	Time
TAL	Time After Launch (s)
TGC	Transmitter Gain Control
Tr	Traverse Angle (deg)
UHF	ALTAIR Frequency; 415 MHz
V	Velocity
V_d	Doppler Velocity
V_w	Mean Wake Velocity
VHF	ALTAIR Frequency; 155.5 MHz
WB	Wide Band
WBS	Wide Band Slaved
WTR	Western Test Range
θ	Total Off-axis Angle (deg)
λ	Wavelength
*	Denotes Multiplication

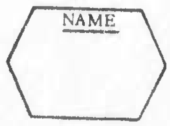
FLOW DIAGRAM SYMBOLS

PROCESS, ANNOTATION



DECISION

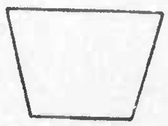
TERMINATOR



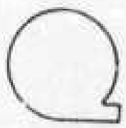
SUBROUTINE: where NAME is the entry call into the subroutine

CONNECTOR: where P specifies a page in the flow diagram, and L designates a statement number in the program listing or a reference point in the flow diagram

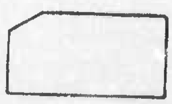
CONNECTOR: where X implies a continuation of the diagram to the next page



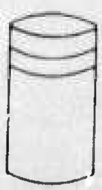
INPUT/OUTPUT OPERATION



MAGNETIC TAPE



PUNCHED CARD



DISK

ALTPOD

I. PURPOSE AND UTILIZATION

A. Source of Data

ALTAIR[1]

B. Data Input

ALTAIR catalog tape

C. Description

ALTPOD is designed to produce punched card metric data on hard body or chaff targets in a format suitable for input to NRTPOD. The data are ultimately used to obtain a target trajectory, pierce and impact points, and a β profile. ALTPOD is normally run every 0.1 s.

D. Output

1. A listing of computed quantities.
2. Plots vs GMT total s of R error, and Az and El offsets. Superimposed on these plots are estimates of the standard deviation of R error and Az and El offsets based on the S/N ratio.
3. Cards, punched in a format suitable for input to NRTPOD, containing R, Az, and El corrected for biases, tropospheric refraction, ionospheric refraction (optional), and angle offsets (optional).

II. DESCRIPTION

ALTPOD produces punched metric data for input to * ~~NRTPOD~~ for both exo-atmospheric and re-entry trajectory determination. ALTPOD automatically corrects the data for known biases and tropospheric refraction. Optional corrections for off-axis position and ionospheric refraction are available. Ionospheric refraction corrections should be applied when the target is in or above the ionosphere. Off-axis corrections should be made when the angular rates are sufficient to cause the antenna

Range signal-to-noise ratio, range azimuth elevation

to lag. R error, ~~S/N~~, and the standard deviations of R error and Az and El offsets are listed to help evaluate * ~~NRTPOD~~ results.

The computations performed by ALTPOD depend on the ARTP version used at Kwajalein.# Since 12 March 1971, R, Az, and El are corrected for known biases prior to recording on the catalog tape. Before 12 March 1971, R, Az, and El were corrected for biases by the ALTPOD program.

A. R, Az, and El

R, Az, and El are corrected for known biases and tropospheric refraction as follows:

1. Prior to 12 March 1971

$$R = [I_R(85) + I_R(86) + I_{11}(3)] - \Delta R + \Delta R_i$$

where

$I_R(85) + I_R(86)$ is the unambiguous range found in FMRDRM, Items 85 and 86

$I_{11}(3)$ is range bias found in Calibration Record FMRR11, Item 3

ΔR is tropospheric refraction correction

ΔR_i is ionospheric refraction correction (optional)

#Found in FMHDRD, Items 10 and 11.

* non-real time precision orbit ② determination program

$Az_t = I_R(13)_{(t-25\ ms)} + I_C(3) + \text{Az offset (optional)}$

where

Az_t = Az at time t

$I_R(13)_{(t-25\ ms)}$ is Az encoder angle found in FMRDRM, Item 13 at time t -25 ms

$I_C(3)$ is Az bias found in Calibration Record FMAACC, Item 3

$El_t = I_R(14)_{(t-25\ ms)} + I_C(5) - \Delta E + \Delta E_i + \text{El offset (optional)}$

where

El_t = El at time t

$I_R(14)_{(t-25\ ms)}$ is El encoder angle found in FMRDRM, Item 14 at time t -25 ms

$I_C(5)$ is El bias found in FMAACC, Item 5

ΔE is tropospheric refraction correction

ΔE_i is ionospheric refraction correction (optional)

2. On or After 12 March 1971

$R = [I_R(85) + I_R(86)] - \Delta R + \Delta R_i$ (optional)

$Az = I_R(13) + \text{Az offset (optional)}$

$El = I_R(14) - \Delta E + \Delta E_i \text{ (optional)} + \text{El offset (optional)}$

B. Az Offset

$$\text{Az offset (deg)} = \frac{\text{VHF Tr error (V)}}{\text{VHF LC sum (V)}} * \frac{1}{\Delta\text{Tr slope}} * \frac{1}{\cos El} * XK$$

where

VHF Tr error is found in FMRDRM, Item 19, if ALTAIR is in the point target tracking mode and in FMRDRM, Item 99, if ALTAIR is in the chaff tracking mode.#

#The mode is found in FMRDRM, Item 107.

VHF LC sum is found in FMRDRM, Item 23, if ALTAIR is in point target tracking mode and in FMRDRM, Item 104, if ALTAIR is in chaff tracking mode.

ΔTr slope is found in Calibration Record FMRR05, Item 2, if ALTAIR is in point target tracking mode and in Calibration Record FMR5CH, Items 2-6, if ALTAIR is in chaff tracking mode.

XK is a conversion factor from mrad to deg

C. El Offset

$$\text{El offset (deg)} = \frac{\text{VHF El error (V)}}{\text{VHF LC sum (V)}} * \frac{1}{\Delta\text{El slope}} * \text{XK}$$

where

VHF El error is found in FMRDRM, Item 20, if ALTAIR is in point target tracking mode and in FMRDRM, Item 100, if ALTAIR is in chaff tracking mode.

ΔEl slope is found in FMRR05, Item 4, if ALTAIR is in point target tracking mode and in FMR5CH, Items 12-16, if ALTAIR is in chaff tracking mode.

D. Ionospheric Refraction Corrections#

1. ΔR_i

$$\Delta R_i = -1.166\ (R_V - R_U)$$

where

R_V is range from VHF range tracker

R_U is range from UHF range tracker

2. ΔE_i

$$\Delta E_i = \text{Cot El} * \frac{R_V - R_U}{R} * \frac{1 + B}{C} * Z$$

where

$$B = R/r_e \sin \text{El}$$

where

r_e is radius of the earth

#Called RIOC and ELCIO in listing.

$$C = \frac{1 + Alt_p (2 r_e + Alt_p)}{(r_e \sin El)^2}$$

where

Alt$_p$ is altitude of peak electron density

$$Z = 1 + B\sigma/(1 + B \mu_p) * e^{-A^2} / \sqrt{\frac{\pi}{2}} \ [1 + \text{erf}(A)]$$

$$\sigma = \sigma_h / R \sin El \ [1 + B \mu_p (\cos El)^2]$$

where

σ_h is width of the ionosphere

$\mu_p = (C - 1)/B$

$A = (1 - \mu_p)/\sigma$

erf is an error function: $\frac{2}{\sqrt{\pi}} \int_0^x e^{-\mu^2} du$

where

$x = A$

E. R Error

$$R \text{ error (m)} = \frac{\text{VHF R error (V)}}{\text{VHF LC sum (V)}} * B_M * K$$

where

VHF R error is found in FMRDRM, Item 18, if ALTAIR is in the point target tracking mode and in FMRDRM, Item 98, if ALTAIR is in the chaff tracking mode.

VHF LC sum is found in FMRDRM, Item 23, if ALTAIR is in point target tracking mode and in FMRDRM, Item 104, if ALTAIR is in chaff tracking mode.

B_M is the range channel slope (yd/V/V). For point target track mode, B_M is found in Calibration Record FMRR06 as a function of track reference and waveform. VHF waveform is determined by combining FMRDRM, Items 3 and 28. Track reference

(centroid, leading edge, or trailing edge) is found in FMRDRM, Item 61. For chaff target track mode, B_M is found in Calibration Record FMRCHF as a function of tracking gate width (found in FMRDRM, Item 107). K converts yd to m.

F. S/N

$$S/N\ (db) = TGC + 2.2 - 10 * (\text{sensitivity bit})$$

where

TGC is VHF TGC attenuation, found in FMRDRM, Item 26. The sensitivity bit is found in FMRDRM, Item 51.

G. Standard Deviations of R Error and Az and El Offsets

The standard deviations (σ) of R error and Az and El offsets are computed:

$$\sigma_{\text{Az offset}}\ (\text{deg}) = \frac{40}{\sqrt{S/N}} * \frac{1}{\cos El} * Z$$

$$\sigma_{\text{El offset}}\ (\text{deg}) = \frac{40}{\sqrt{S/N}} * Z$$

$$\sigma_{\text{R error}}\ (\text{m}) = \frac{21.75}{\sqrt{S/N}}$$

where

Z is a conversion factor from mrad to deg

III. OPERATION

A. Input

Start and stop times (GMT)

Sensor identification

Date of test

Sampling interval (ms)

Options for adding off-axis and ionospheric refraction corrections

A sample input is given in Appendix A.

CARD 1 [(A3, 1X, 3I2, 2 (10X, 3I2, 1XI3), 1XI4, 2 (4XI1)]

(Col.)			
1- 3	RADAR	Sensor identification	
5- 6	IYEAR	Last two digits of year	Date of test
7- 8	IMON	Month	
9-10	IDAY	Day	
21-22	IHR	(h)	Start time (GMT)
23-24	IMN	(min)	
25-26	ISC	(s)	
28-30	ISTH#	(ms)	
41-42	IEHR	(h)	Stop time (GMT)
43-44	IEMN	(min)	
45-46	IESC	(s)	
48-50	IETH#	(ms)	
52-55	ITV#	Sampling interval (ms)	
60	IOFF	Angle offset option: 1 = add offsets; 0 = do not add offsets	
65	IONC	Ionospheric refraction correction option; 1 = add offsets; 0 = do not add offsets	

#Must be multiple of 25 ms.

CARD 2

(Col.)

1-72 LABEL 72 character label for plots

B. Output

LISTING

GMT h, min, and s

R and El ionospheric corrections (optional)

R, Az, and El

R error (m)

Az and El offsets (deg)

S/N (db)

Standard deviations of R error and Az and El offsets

PLOTS

R error and standard deviation of R error vs GMT total s

Az offset and standard deviation of Az offset vs GMT total s

El offset and standard deviation of El offset vs GMT total s

PUNCHED CARDS

Sensor identification	(A3)
Year	(3XI2)
Month	(I2)
Day	(I2)
h	(I2)
min	(I2)
s	(I2)
Fraction of second	(I5)
Az	(F9.3)
El	(F12.3)
R	(F16.6)

Sample outputs are given in Appendix B.

IV. PROGRAM LIMITATIONS

ITV ≤ 9999

Do not add angle offsets unless an examination of ALTCEP[2] shows they are well behaved and there is a sufficient S/N.

Do not add ionospheric refraction corrections unless target is in range track at VHF and UHF (see ALTCEP listing).

V. PROGRAMMING

A. ALTPDO (see Appendices C and D.)

ALTPDO is the control section of ALTPOD. ALTPDO reads the input cards, and prints and punches the data. ALTPDO calls CHEAD, BMFND, REA, WHDATE, and the plotting routines. ALTPDO also calls WHICHV, a 360-system subroutine indicating whether a job is being run under the time-sharing (CMS) or Batch (OS) systems.

B. BMFND (see Appendix E.)

Subroutine BMFND contains a table of constants used in computing range error. The call statement is BMFND.

STORED IN COMMON	
B_M	Range channel slope (yd/V/V)

C. CHEAD (see Appendices F and G.)

CHEAD is used to process calibration and format records which are recorded before the data records on the ALTAIR transcription tape. CHEAD lists format and calibration records named in the common statement. These are stored and unpacked for later use by the main processing program. A sample CHEAD output is given in Appendix H.

The minimum size needed for the item array may be calculated by the following equation:

Item size = 6 * (Total number of items stored) + (6 * 130)

Calling Sequence: Call CHEAD (*)

* = A return point specified by a statement number in the calling program. Used for aborting job by main program if wrong tape is mounted.

CHEAD calls the following subroutines:

BREADS (entries BREADS and BREAD); HDRR (entries HDRR and NAMET); and FORM.[3]

D. WHDATE (see Appendix J.)

Subroutine WHDATE determines whether the ARTP version was on or after 12 March 1971. The call statement is WHDATE (IDARR (9), IDARR (10), NEW).

INPUT

IDARR (9)	Day and first two letters of month
IDARR (10)	Third letter of month and last two numbers of year

OUTPUT

NEW	Date of Tape: 1 = On or after 12 March 1971 2 = Prior to 12 March 1971

E. REA (see Appendices K and L.)

Subroutine REA reads and computes data from the catalog tape. REA calls GET and IGET, HMS, HM25, BZERO, IONCOR, and REFC. The call statement is REA (DTIME, ICC, IONC).

INPUT

DTIME	Time of record to be processed
IONC	Ionospheric refraction correction option

INPUT AND OUTPUT

ICC	No. of records processed

STORED IN COMMON

GMT	Total GMT seconds
RNG2	R
R	Not used
E	El
A	Az
DF	Range tropospheric refraction correction

F18	Range error (m)
F19	Az offset (deg)
F20	El offset (deg)
N23	VHF LC Sum (V)
SNDB	S/N (db)
DTHETA	Standard deviation of Az and El offsets
DRANG	Standard deviation of Range error (m)

F. GET and IGET

GET and IGET are entries to subroutine GETS.[3]

These routines will locate any data item, unpack it, and interpret it according to the information in the format table. They will return the item as a binary integer (in the case of IGET) or as a floating point number (in the case of GET).

GET (or IGET) requires three arguments:

GET (Format, Base, Item)

Format	Relevant format table address
Base	Base address of data block desired
Item	Specific item number

G. HMS (see Appendix M.)

Subroutine HMS unpacks the time words found in FMRDRM, Items 1 and 2, and converts them into h, min, s, and ms. The call statement is HMS (IW1, IW2, IH, IM, IS, IT).

INPUT

IW1	FMRDRM, Item 1
IW2	FMRDRM, Item 2

OUTPUT

IH	Hours
IM	Minutes
IS	Seconds
IT	Decimal fractions of seconds

H. HM25 (see Appendix N.)

Subroutine HM25 computes the TGC attenuation found in FMRDRM, Item 25. The call statement is HM25 (LALL, IHMCH).

INPUT

LALL	FMRDRM, Item 25

OUTPUT

IHMCH	TGC attenuation (db)

J. BZERO (see Appendix O.)

Subroutine BZERO is necessary if a floating point item is scaled B0 in a format or calibration table description. BZERO is called after the item has been extracted by subroutine GETS.[3] BZERO normalizes the data item and puts the decimal point in its proper position. The call statement is BZERO (yy).

INPUT AND OUTPUT

yy	Item to be processed

K. IONCOR (see Appendix P.)

Subroutine IONCOR computes elevation angle corrections (deg) to compensate for ionospheric refraction. The call statement is IONCOR (ALTP, SIGMAH, RANGE, ELEV, DELTAR, DELTAE).

INPUT

ALTP	Alt of peak electron density
SIGMAH	Width (km) of the ionosphere
RANGE	R for each requested time
ELEV	El for each requested time
DELTAR	VHF - UHF range difference, found in FMRDRM, Item 75

OUTPUT

DELTAE	El correction

L. REFC (see Appendix Q.)

The tropospheric refraction correction subroutine, REFC, is based on tropospheric refraction tables in PPP-36.[4] A modified version of this subroutine is now in use.

The call statement is REFC (E, R, DEE, DRR)

E	Uncorrected El (must be between 0° and 90°)
R	Uncorrected R (ft)
DEE	El tropospheric correction
DRR	R tropospheric correction (ft)

The corrected values to be computed after exiting from REFC are:

El = E - DEE
R (ft) = R - DRR

M. ALTPLT

ALTPLT is the plotting routine.

N. REREAD

REREAD is a plotting system subroutine.

REFERENCES

1. "ALTAIR Data User's Manual", LM-97, Lincoln Laboratory, M.I.T. (to be published).

2. "Data Reduction Program Documentation, ALTCEP, (Effective: July 1971)", PA-229-12, Lincoln Laboratory, M.I.T. (8 July 1971).

3. "Data Reduction Program Documentation, ALTAIR Tape Read Package, (Effective: April 1970)", PA-229-1, Lincoln Laboratory, M.I.T. (17 March 1971).

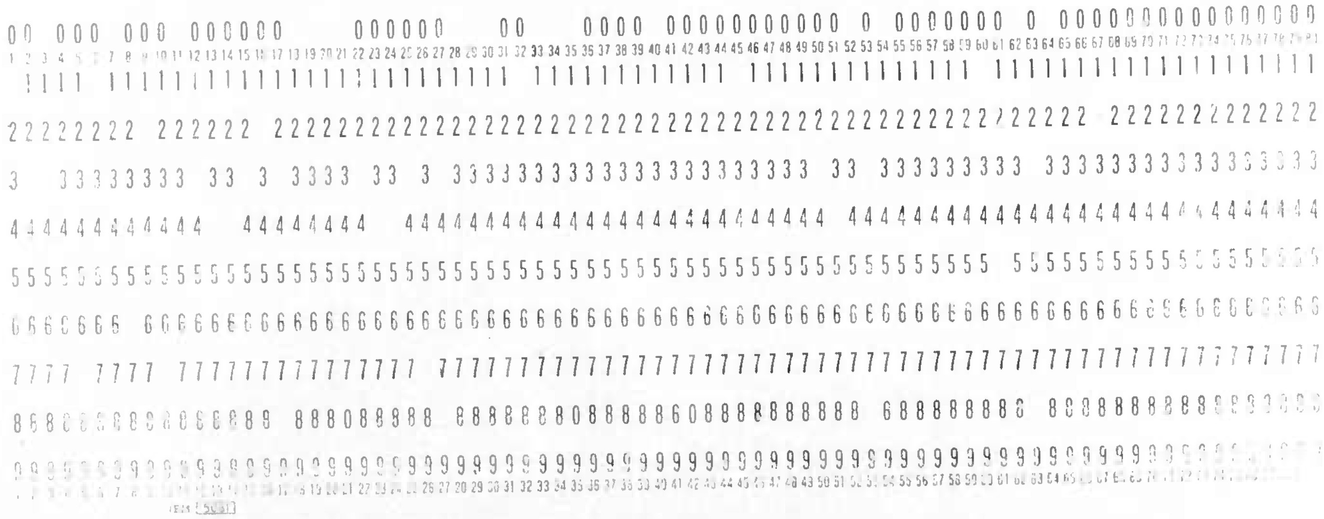
4. J. P. Penhune, "Refraction Corrections for the TRADEX Radar", PPP-36, Lincoln Laboratory, M.I.T. (21 April 1965).

APPENDIX A

ALTPOD INPUT

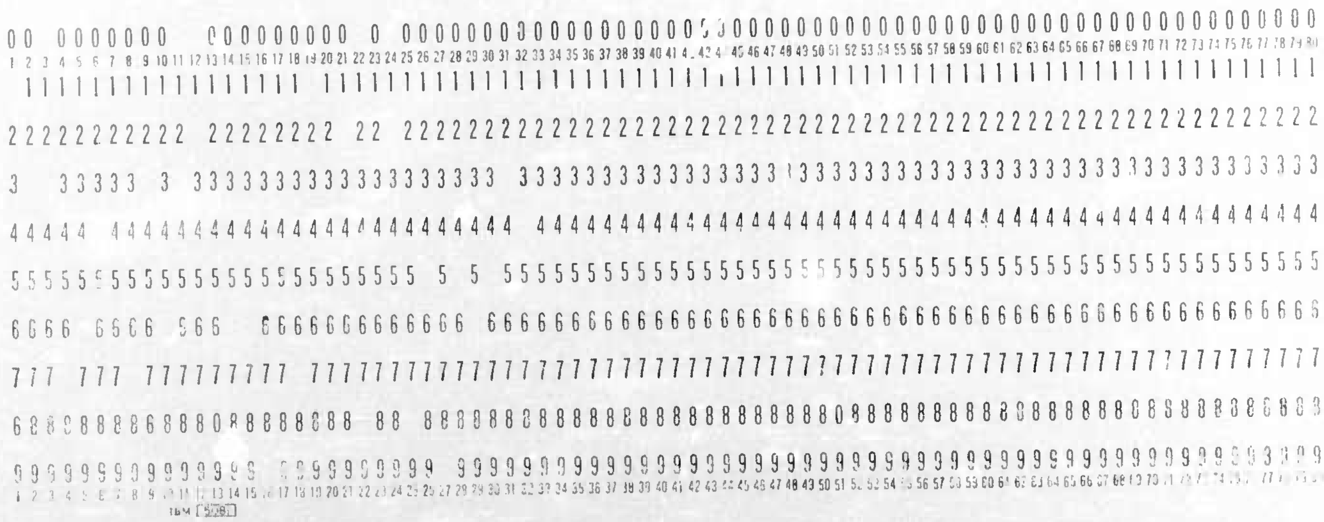
```
ALT 710627034432.000034437.000 1000     0     1     340.0      150.0
```

CARD 1



```
ALTPOD PLOTS FOR PA BY SHEINFELD
```

CARD 2

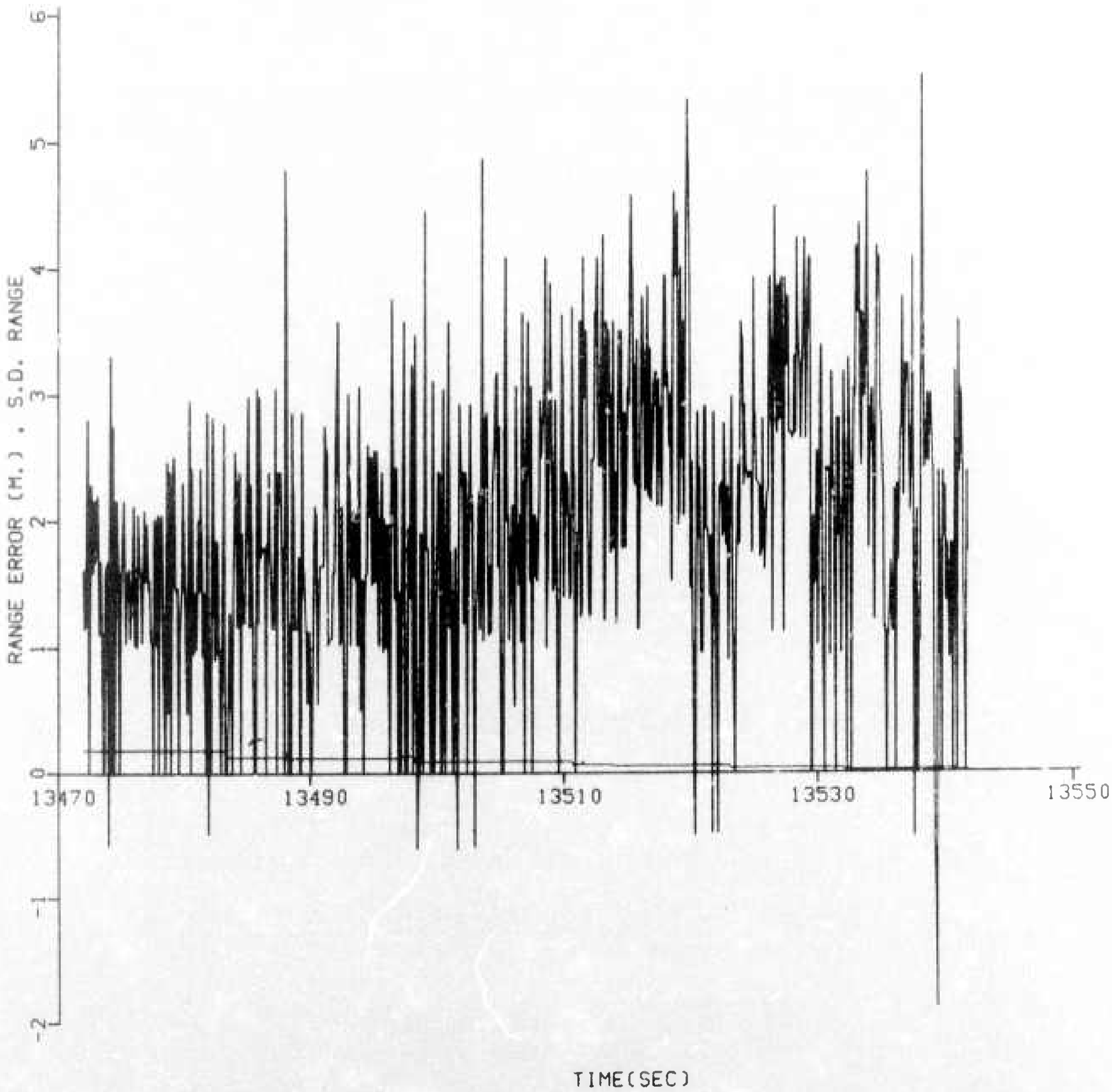


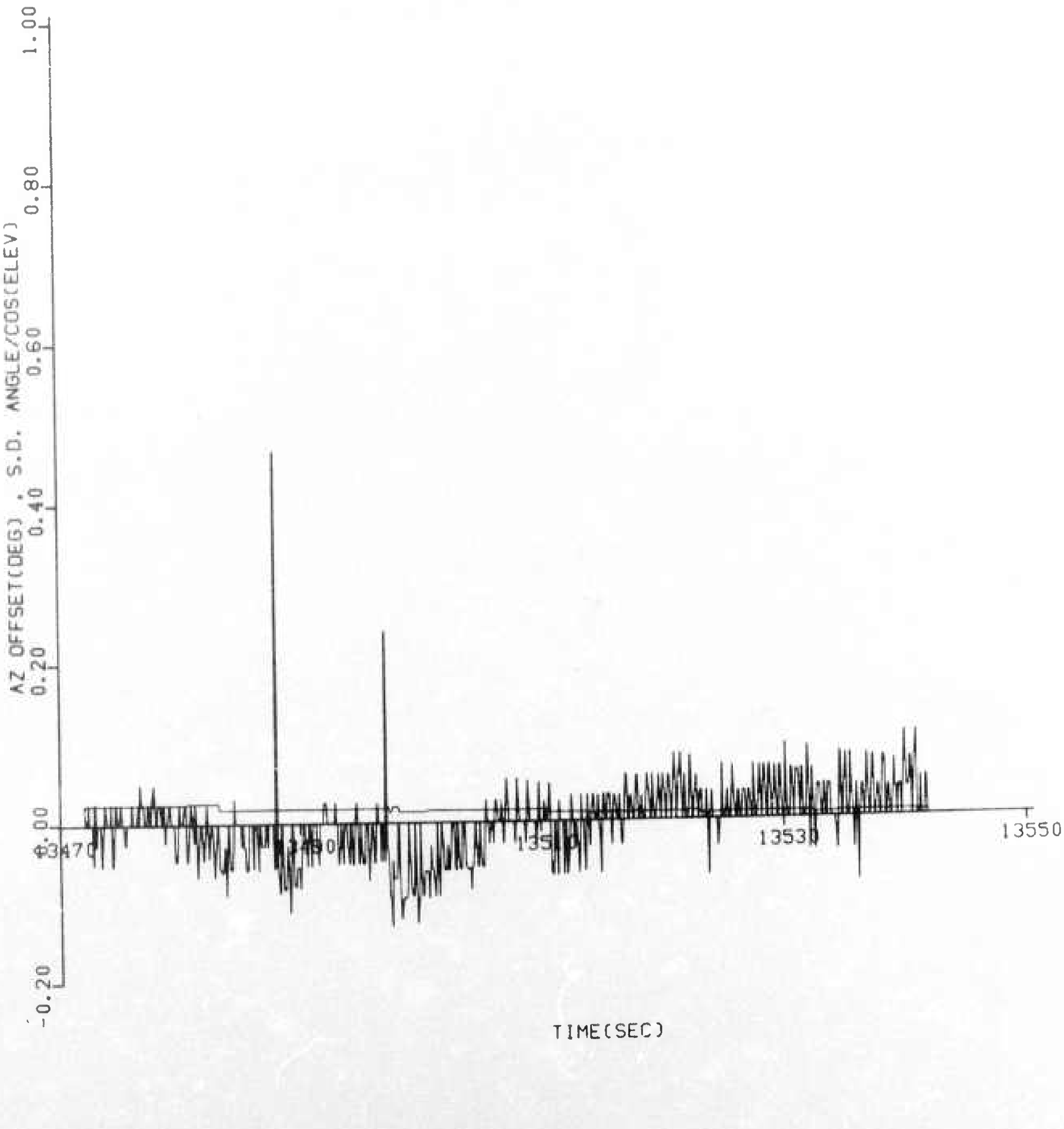
APPENDIX B

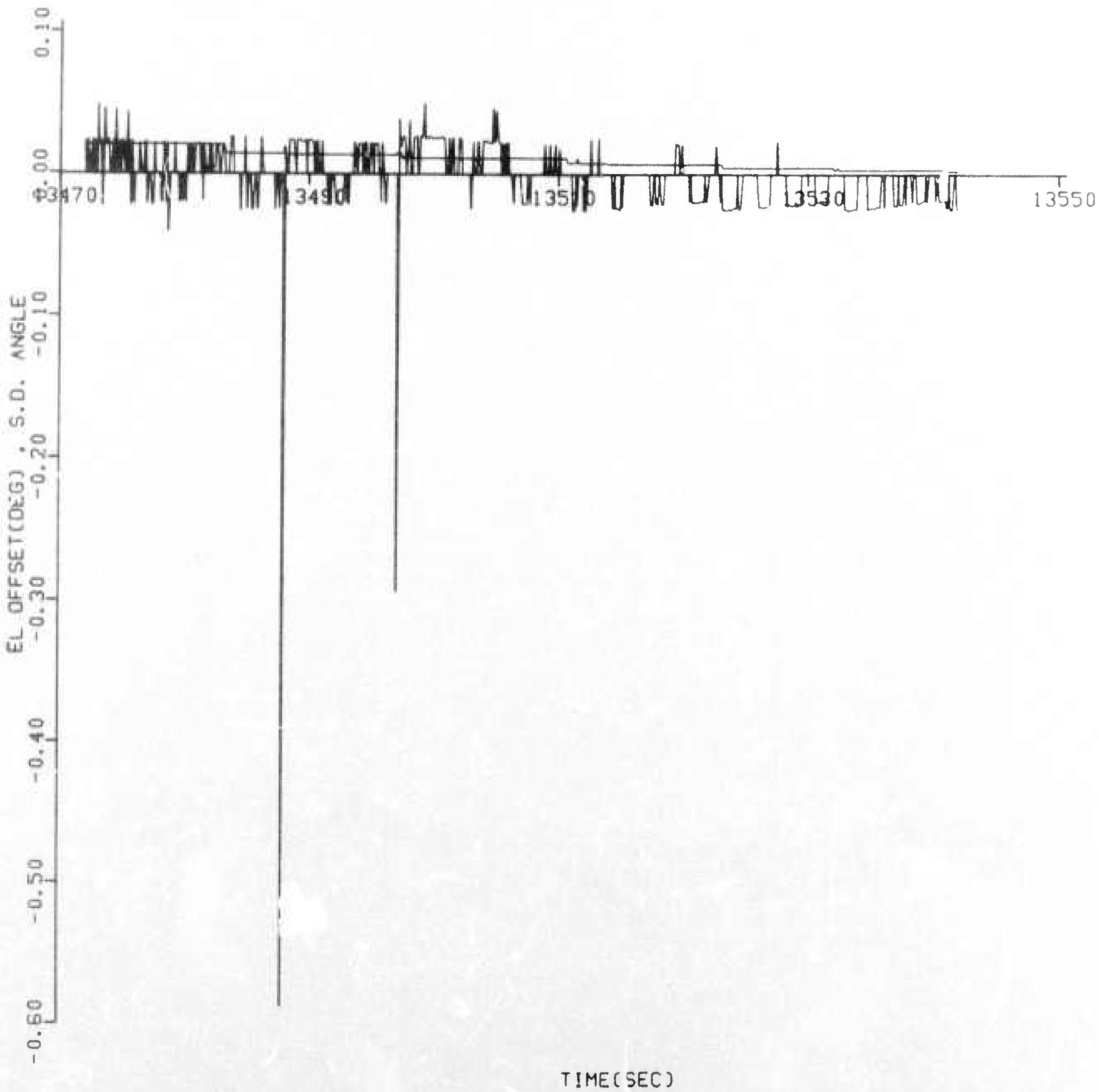
ALTPOD OUTPUTS

NEW TAPE
START = 3:44:32. 0
STOP = 3:44:37 0
INTERVAL OF 100 THOUSANDTHS
OFFSETS ADDED NO
IONOSPHERIC CORRECTION YES
PEAK = 450.00 WIDTH = 200.00
TAPE DATE 27JUN71

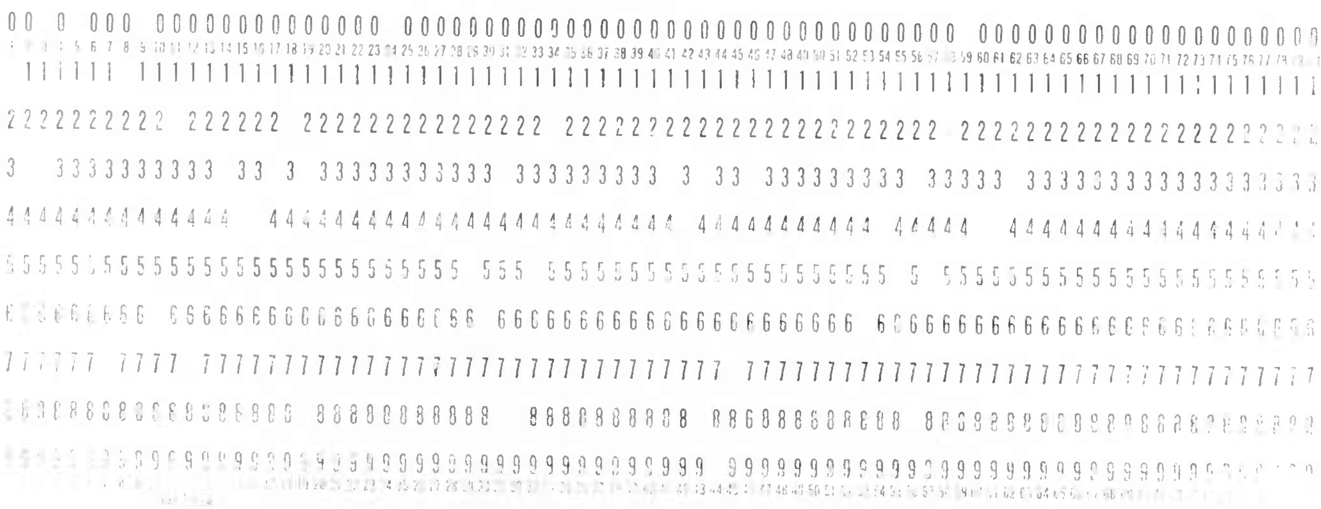
H M SEC	RIDC	ELCID	ELEV	AZIM	UNAMB RAN	DEL RA	DEL AZ	DEL EL	SNDB	SD EL	SD RANGE	SD AZ
3 44 32. 0	0.382	0.037	34.974	56.852	645.520	-1.82	0.025	0.022	32.2	0.020	0.19	0.024
3 44 32.100	0.377	0.037	34.985	56.852	644.900	-1.28	0.0	0.0	32.2	0.020	0.19	0.024
3 44 32.200	0.381	0.[illegible]37	35.001	56.852	644.272	-1.31	0.0	0.0	32.2	0.020	0.19	0.024
3 44 32.300	0.377	0.037	35.018	56.852	643.648	-1.89	0.0	0.023	32.2	0.020	0.19	0.024
3 44 32.400	0.377	0.037	35.032	56.849	64[illegible].023	-3.15	0.026	0.0	32.2	0.020	0.19	0.024
3 44 32.500	0.375	0.037	35.045	56.849	642.399	0.0	0.0	0.0	32.2	0.020	0.19	0.024
3 44 32.600	0.373	0.037	35.062	56.849	641.776	-2.57	0.0	0.023	32.2	0.020	0.19	0.024
3 44 32.700	0.373	0.037	35.076	56.849	641.151	-1.85	0.0	0.0	32.2	0.020	0.19	0.024
3 44 32.800	0.372	0.037	35.095	56.846	640.526	-1.78	-0.050	0.022	32.2	0.020	0.19	0.024
3 44 32.900	0.372	0.037	35.106	56.843	639.900	-2.42	0.025	0.022	32.2	0.020	0.19	0.024
3 44 33. 0	0.370	0.036	35.120	56.841	639.276	-1.89	0.026	0.0	32.2	0.020	0.19	0.024
3 44 33.100	0.370	0.036	35.139	56.841	638.652	-1.97	-0.027	0.048	32.2	0.020	0.19	0.024
3 44 33.200	0.370	0.036	35.153	56.841	638.026	-2.47	0.0	0.023	32.2	0.020	0.19	0.024
3 44 33.300	0.369	0.036	35.173	56.838	637.40[illegible]	-1.24	0.0	0.023	32.2	0.020	0.19	0.024
3 44 33.400	0.368	0.036	35.184	56.838	636.778	-1.89	0.0	-0.023	32.2	0.020	0.19	0.024
3 44 33.500	0.368	0.036	35.197	56.835	636.152	-1.26	-0.053	0.0	32.2	0.020	0.19	0.024
3 44 33.600	0.366	0.036	35.217	56.832	635.528	0.0	-0.025	0.044	32.2	0.020	0.19	0.024
3 44 33.700	0.364	0.036	35.231	56.830	634.904	0.0	0.0	0.022	32.2	0.020	0.19	0.024
3 44 33.800	0.366	0.036	35.250	56.830	634.277	-1.78	0.025	0.022	32.2	0.020	0.19	0.024
3 44 33.900	0.364	0.036	35.264	56.827	633.653	-1.89	0.0	0.023	32.2	0.020	0.19	0.024
3 44 34. 0	0.363	0.036	35.283	56.827	633.029	0.64	0.0	0.0	32.2	0.020	0.19	0.024
3 44 34.100	0.361	0.036	35.294	56.827	632.404	-1.89	0.0	0.0	32.2	0.020	0.19	0.024
3 44 34.200	0.359	0.036	35.308	56.824	631.779	-3.71	0.0	0.0	32.2	0.020	0.19	0.024
3 44 34.300	0.363	0.036	35.327	56.821	631.153	0.0	0.025	0.022	32.2	0.020	0.19	0.024
3 44 34.400	0.357	0.035	35.349	56.819	630.529	-3.09	-0.052	0.0	32.2	0.020	0.19	0.024
3 44 34.500	0.358	0.036	35.363	56.819	629.906	0.0	-0.051	0.044	32.2	0.020	0.19	0.024
3 44 34.600	0.357	0.035	35.[illegible]82	56.816	629.278	-2.42	0.025	0.0	32.2	0.020	0.19	0.024
3 44 34.700	0.357	0.035	35.399	56.816	628.655	-2.42	0.025	0.0	32.2	0.020	0.19	0.024
3 44 34.800	0.356	0.035	35.415	56.813	628.030	-1.85	0.0	0.023	32.2	0.020	0.19	0.024
3 44 34.900	0.353	0.035	35.432	56.810	627.406	0.0	0.0	0.0	32.2	0.020	0.19	0.024
3 44 35. 0	0.356	0.035	35.449	56.80[illegible]	626.779	-1.21	0.0	0.022	32.2	0.020	0.19	0.024
3 44 35.100	0.354	0.035	35.462	56.808	626.154	-1.82	0.026	0.022	32.2	0.020	0.19	0.024
3 44 35.200	0.352	0.035	35.482	56.808	625.531	-2.42	0.0	0.0	32.2	0.020	0.19	0.024
3 44 35.300	0.352	0.035	35.496	56.805	624.905	-1.82	0.0	0.022	32.2	0.020	0.19	0.024
3 44 35.400	0.351	0.035	35.509	56.805	624.281	-1.17	-0.025	0.04[illegible]	32.2	0.020	0.19	0.024
3 44 35.500	0.350	0.035	35.526	56.802	623.656	-1.78	-0.025	0.0	32.2	0.020	0.19	0.024
3 44 35.600	0.350	0.035	35.540	56.802	623.029	-1.78	0.0	0.022	32.[illegible]	0.020	0.19	0.024
3 44 35.700	0.347	0.035	35.559	56.799	622.407	-1.82	0.0	-0.022	32.2	0.020	0.19	0.024
3 44 35.800	0.348	0.035	35.573	56.797	621.781	-1.21	0.0	0.022	32.2	0.020	0.19	0.024
3 44 35.900	0.348	0.035	35.592	56.797	621.154	-1.75	0.0	-0.021	32.2	0.020	0.19	0.024
3 44 36. 0	0.345	0.035	35.606	56.797	620.530	-2.38	0.025	0.0	32.2	0.020	0.19	0.024
3 44 36.100	0.341	0.034	35.626	56.794	619.907	-1.15	0.0	0.0	32.2	0.020	0.19	0.024
3 44 36.200	0.344	0.034	35.639	56.794	619.280	-1.69	0.0	0.0	32.2	0.020	0.19	0.024
3 44 36.300	0.344	0.034	35.658	56.794	618.655	-1.13	0.0	0.0	32.2	0.020	0.19	0.024
3 44 36.400	0.342	0.034	35.675	56.791	618.030	-2.29	0.0	0.021	32.2	0.020	0.19	0.024
3 44 36.500	0.342	0.034	35.692	56.788	617.404	-1.78	0.025	0.0	32.2	0.020	0.19	0.024
3 44 36.600	0.338	0.034	35.706	56.788	616.781	-1.78	0.0	0.0	32.2	0.020	0.19	0.024
3 44 36.700	0.342	0.034	35.725	56.786	616.153	-1.17	0.049	0.0	32.2	0.020	0.19	0.024
3 44 36.800	0.337	0.034	35.739	56.786	615.530	-1.75	0.025	0.021	32.2	0.020	0.19	0.024
3 44 36.900	0.339	0.034	35.758	56.783	614.903	-2.34	0.025	0.021	32.2	0.020	0.19	0.024


RANGE ERROR (M.) . S.D. RANGE
6
5
4
3
2
1
0
-1
-2
13470
13490
13510
13530
13550
TIME(SEC)


AZ OFFSET(DEG) . S.D. ANGLE/COS(ELEV)
-0.20
0.00
0.20
0.40
0.60
0.80
1.00
13530
13550
TIME(SEC)


0.10
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
EL OFFSET(DEG) , S.D. ANGLE
13550
TIME(SEC)

PLT 0 710627 34432. 0 56.852 34.973 645.520443



APPENDIX C

ALTPDO PROGRAM LISTING

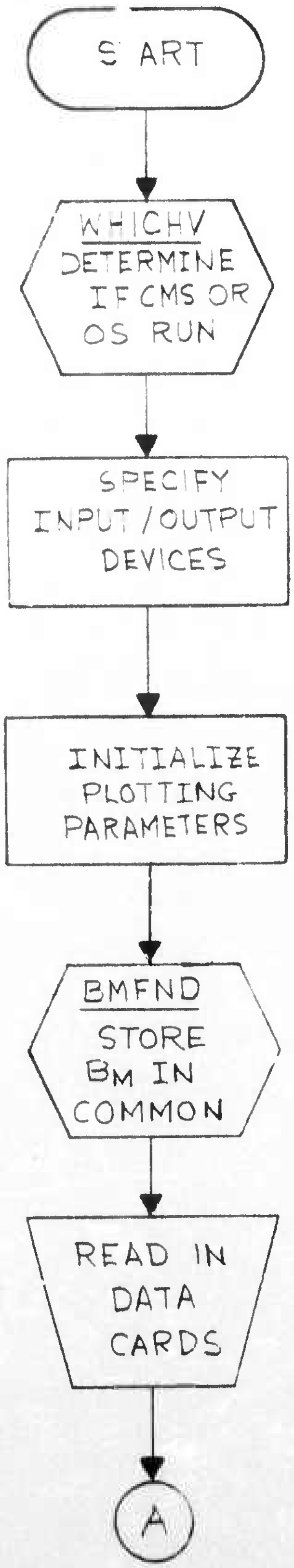
```
C      INPUT PARAMETERS (ALL ARE INTEGERS EXCEPT SENSOR WHICH IS ALPHA)
C                      (AND PEAK AND WIDTH WHICH ARE REAL FORMAT F6.2)
C     COLUMNS        PARAMETER
C       1- 3         SENSOR
C       5-10         YEAR, MONTH, DAY OF FLIGHT
C      11-16         START HOUR, MINUTE, SECOND
C         17         .
C      18-20         START THOUSANDTHS OF A SECOND
C      21-26         STOP HOUR, MINUTE, SECOND
C         27         .
C      28-30         STOP THOUSANDTHS OF A SECOND
C      32-35         INTERVAL IN THOUSANDTHS OF A SECOND
C         40         1=ADD OFFSETS, 0=NO OFFSETS ADDED
C         45         1=USE IONSPHERIC CORRECTION ON THE RANGE, 0=NOT USED
C      50-55         PEAK ALTITUDE FOR IONOSPHERIC CORRECTION FORMAT F6.2
C      60-65         WIDTH OF IONOSPHERE FORMAT F6.2
C         70         0=USE TAPE DATE, 1=NEW TAPE, 2=OLD TAPE
C   NOTEO IF NO IONOSPHERIC CORRECTION PEAK AND WIDTH MAY BE 0.0,
C          IF IONOSPHERIC CORRECTION  AND PEAK AND WIDTH NOT SPECIFIED,
C             NOMINAL VALUES OF PEAK= 340.0, AND WIDTH = 150.0 ARE USED
C    CARD 2 IS LABEL INFORMATION (72 ALPHAMERIC LIMIT FOR PLOTS) CS ONLY
C       THIS CARD MUST BE HERE AND NOT BLANK FOR PLOTS
C
      REAL * 8 START,STOP,RNG2,DTIME,DINT,XX,GMT,DXT,G3,R3,A3,E3
      INTEGER*2 ITEM
      COMMON/BEAD/LN,IFLG,IADD,FMRDID,FMCATF,FMCSAD,FMCMDB,FMCTIB,FMCIDB
     1,FMCTDB,FMRDRD,FMRDRM,FMRDRT,FMGLOT,FMRR05,FMAXSP,FMBIAS,FMR5CH
     2,FMRCHF,FMAACC,FMRR11,NAME(19),NI(18),IX(18),ITEM(8000)
      COMMON /DRMDTA/GMT,RNG2,R,E,A,DF,F18,F19,F20,N23
      COMMON /SDATA/SNDB,DTHETA,DRANS
      COMMON /IOCORS/RCIO,ELCIO,ALTI,SIGH
      COMMON /KTAPE/NEW
      COMMON /TITLE/ IDARR(10)
      COMMON /P4060/LEG(18)
      DIMENSION G3(2),R3(2),A3(2),E3(2),NOFF(2),NTPE(2)
      DIMENSION GP(700),F18P(700),F19P(700),F20P(700),SDR(700),SCA(700),
     1   SDCE(700)
      DATA NOFF/'NO  ','YES '/
      DATA NTPE/'NEW ','OLD '/
      DATA ICMS/'CMS '/
      DATA IBL/'    '/
      INPUT = 5
      IOUTPT = 6
      NO8 = 1
      NO7 = 1
      DO 7744 I = 1,18
      LEG(I) = IBL
7744  CONTINUE
      CALL WHICHV(ID)
      IF(ID.NE.ICMS) GO TO 10000
      PRINT 9951
9951  FORMAT(' FILE 8,1=YES ELSE 0,  FILE 7,1=YES, ELSE 0',/,
     1    ' ENTER TAPE DATE IN THE FORM OF DDMMYY')
      READ(5,9961NO8,NO7,IDARR(9),IDARR(10)
```

```
996   FORMAT(2I1,/,2A4)
      INPUT = 2
      IOUTPT = 8
1000D IPP = 0
      SNOB = D.0
      OTHETA = 0.0
      DRANG = 0.0
      RCIO = 0.0
      ELCIO = 0.0
      IPLKEY = 0
      IP8 = 0
      LI = 0
      IPLOT = 0
      IF(ID.NE.ICMS) CALL REREAO(99)
      CALL BMFND
      IOR8 = 0
      ICC = 0
      CALL CHEAD
      READ(INPUT,991)RADAR,IYEAR,IMON,IDAY,IHR,IMN,ISC,ISTH,
     1   IEHR,IEMN,IESC,IETH,ITV,IOFF,IONC,ALTP,SIGH,MYTAPE
991   FORMAT(A3,IX3A2,2(3I2,1XI3),1XI4,2(4XI1),2(4XF6.2),4XI1)
      IF(ID.EQ.ICMS) GO TO 995
      MPLOT = 0
      READ(INPUT,992,END=995)LEG
992   FORMAT(18A4)
      DO 993 I = 1,18
      IF(LEG(I).NE.IPL) GO TO 994
993   CONTINUE
      GO TO 995
994   MPLOT = 1
995   I100 = ISTH/100
      IM100 = I100 * 100
      IREST = ISTH - IM100
      IF(IREST.GE.1.AND.IREST.LE.24) ISTH = 0
      IF(IREST.GE.26.AND.IREST.LE.49)ISTH = 25
      IF(IREST.GE.51.AND.IREST.LE.74)ISTH = 50
      IF(IREST.GE.76.AND.IREST.LE.99)ISTH = 75
      IF(ALTP.LE.0.D)ALTP = 340.0
      IF(SIGH.LE.D.0)SIGH = 150.0
      NEW = MYTAPE
      IF(MYTAPE.EQ.0) CALL WHOATE(IOARR(9),IOARR(10),NEW)
      XX = ITV
      OINT = XX * 1.00-03
      XX = ISTH
      START = IHR*3600+IMN*60+ISC+XX*1.00-03
      STOP = IEHR*3600+IEMN*60+IESC+FLOAT(IETH)*.001
      STOP = STOP + 2.5D-02
      PRINT 304,NTPE(NEW)
304   FORMAT(' 'A4,'TAPE')
      WRITE(6,303)IHR,IMN,ISC,ISTH,IEHR,IEMN,IESC,IETH,
     1   ITV,NOFF(IOFF+1),NOFF(IONC+1),ALTP,SIGH,IOARR(9),IOARR(10)
303   FORMAT(' START ='2(I2,'0'),I2,'.'I3,/,' STOP = '2(I2,'0'),I2,'.',
     1   I3,/,' INTERVAL OF 'I4,' THOUSANDTHS',/,
     2   ' OFFSETS ADDED 'A4,/,' IONOSPHERIC CORRECTION 'A4,/,
     3   ' PEAK = 'F6.2,'   WIDTH = 'F6.2,/,' TAPE DATE '2A4)
      OTIME = START
      ICC = 1
22    FORMAT('1 H  M  SEC        RIOC    ELCIC     ELEV     ',
     1   'AZIM   UNAMB RAN  ',3X'DEL RA  DEL AZ  DEL EL     '
     2   'SNCB   SD FL   SD RANGE   SD AZ'/)
100   CONTINUE
      DXT = OTIME
101   CONTINUE
      CALL REA(OTIME,ICC,IONC)
      IF(DXT.LE.D.0) DXT = DABS(OTIME)
      LI = LI + 1
      G3(LI) = GMT
      F3(LI) = RNG2
      A3(LI) = A
```

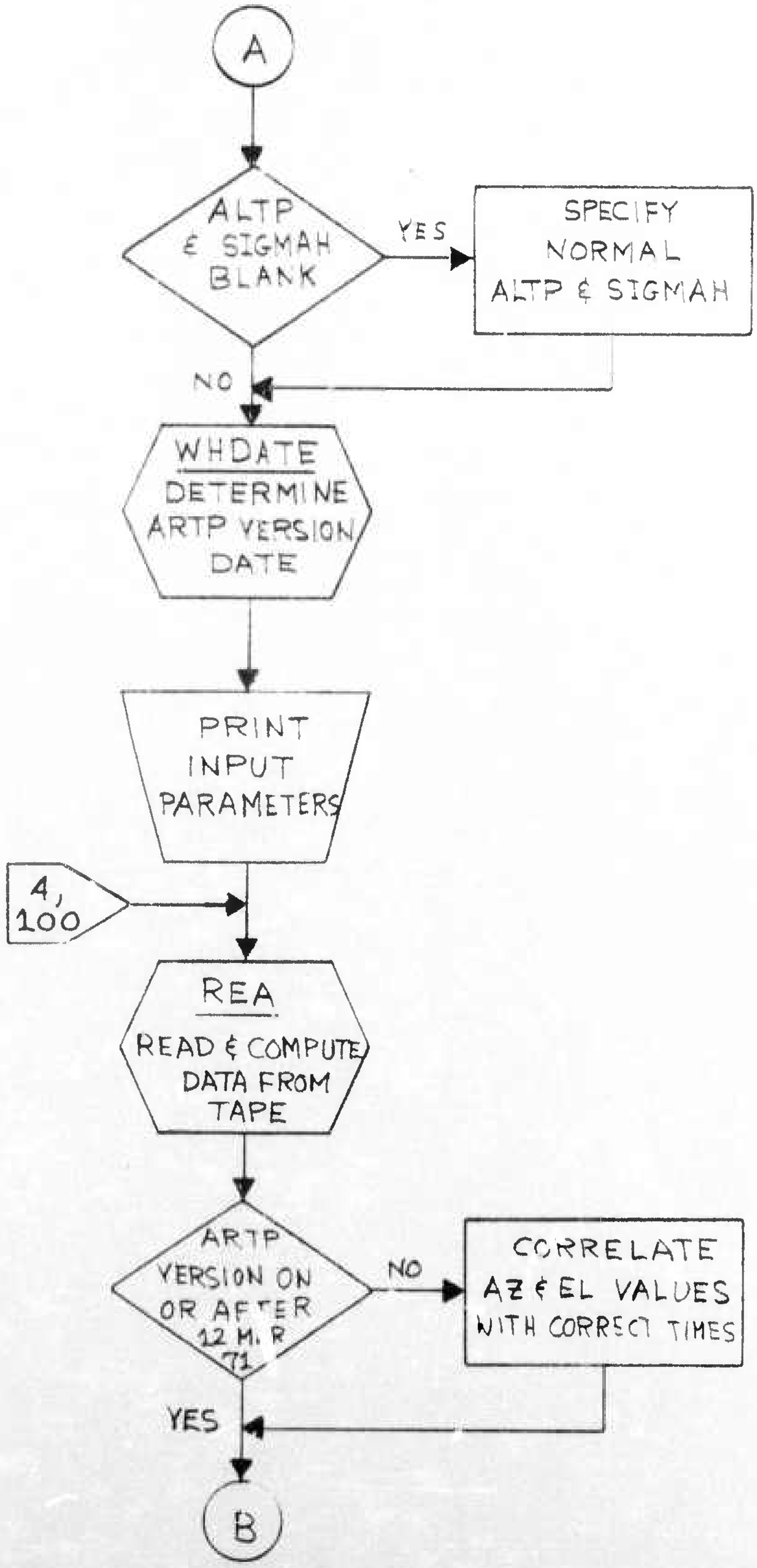
```
      E3(LI) = E
      OTIME = OTIME + 2.5D-02
      IF(LI.EQ.2) GO TO 886
      GO TO 101
886   GMT = G3(1)
      RNG2 = R3(1)
      A = A3(NEW)
      E = E3(NEW)
      LI = 0
      IF(ITV.GE.50) GO TO 7300
      LI = 1
      G3(1) = G3(2)
      R3(1) = R3(2)
      A3(1) = A3(2)
      E3(1) = E3(2)
7300  IF(GMT.GT.STOP) GO TO 200
      DTIME = DXT
      IAHH = GMT/3.6D+03
      IAMIN=(GMT - IAHH*3.6D+03)/6.0D+01
      XX = GMT - IAHH * 3.6D+03-IAMIN*6.0D+01
      IASEC = XX
      IAHSEC = (XX -IASEC +5.0D-04)*1.0D+03
      IAHSEC = IAHSEC*1.0D+02
      IAHSCC = IAHSEC/100
      IF(IOFF.NE.1) GO TO 534
      E = E + F20
      A = A + F19
534   CONTINUE
      IF(MOD(IPP,45).EQ.0.AND.NO8.EQ.1) WRITE(IOUTPT,22)
      OEEP = OTHETA/(COS(E/57.29578))
      IF(NO8.EQ.1)WRITE(IOUTPT,2)IAHH,IAMIN,IASEC,IAHSCC,RCIC,ELCIO,E,A,
     1   RNG2,F18,F19,F20,SNO8,OTHETA,ORANG,OEEP
      IPP = IPP + 1
      IF(NO7.EQ.1)WRITE(7,1071)RADAR,IOR8,IYEAR,IMON,IDAY,
     1   IAHH,IAMIN,IASEC,IAHSEC,A,E,RNG2
2     FORMAT(' 'I2,2(1XI2),'.'I3,1XF8.3,1XF8.3,1X2(F8.3,1X),3XF8.3,
     1   3XF8.2,2X2(F6.3,2X),2XF5.1,3XF5.3,4XF6.2,2XF6.3)
1071  FORMAT(A3,I2,1X3A2,3I2,'.'I5,1XF9.3,F12.3,F16.6)
      IPLOT = IPLOT + 1
      GP(IPLOT) = GMT
      F18P(IPLOT) = F18
      F19P(IPLOT) = F19
      F20P(IPLOT) = F20
      SOR(IPLOT) = ORANG
      SOA(IPLOT) = OTHETA
      SOCE(IPLOT) = OTHETA/(COS(E/57.29578))
      IF(IPLOT.LT.700) GO TO 5665
      IF(MPLOT.EQ.1) CALL ALTPLT(GP,F18P,F19P,F20P,SOR,SOA,SOCE,IPLOT)
      IPLKEY = 1
      IPLOT = 0
5665  CONTINUE
      IF(GMT.GE.STOP) GO TO 200
      IPLKEY = 0
      OTIME = OTIME + OINT
      GO TO 100
200   IGT = IGET (FMCATF,IADO,3)
      IGS = MOD(IGT,16)
      IGS=IGS + (MOD((IGT/16),8)*10)
      IGM = MOD((IGT/256),16)
      IGM = IGM + (MOD((IGT/4096),8)*10)
      IGH=MOD((IGT/65536),16)
      IGH=IGH+(MOD((IGT/1048576),4)*10)
      IGT=IGH*3600+IGM*60+IGS
      XIGT = IGT
      IF((XIGT+10.).LE.GMT) GO TO 100
      IF(MPLOT.NE.1) CALL EXIT
      IF(IPLKEY.EQ.0)CALL ALTPLT(GP,F18P,F19P,F20P,SOR,SOA,SOCE,IPLOT)
      CALL EXIT
      END
```

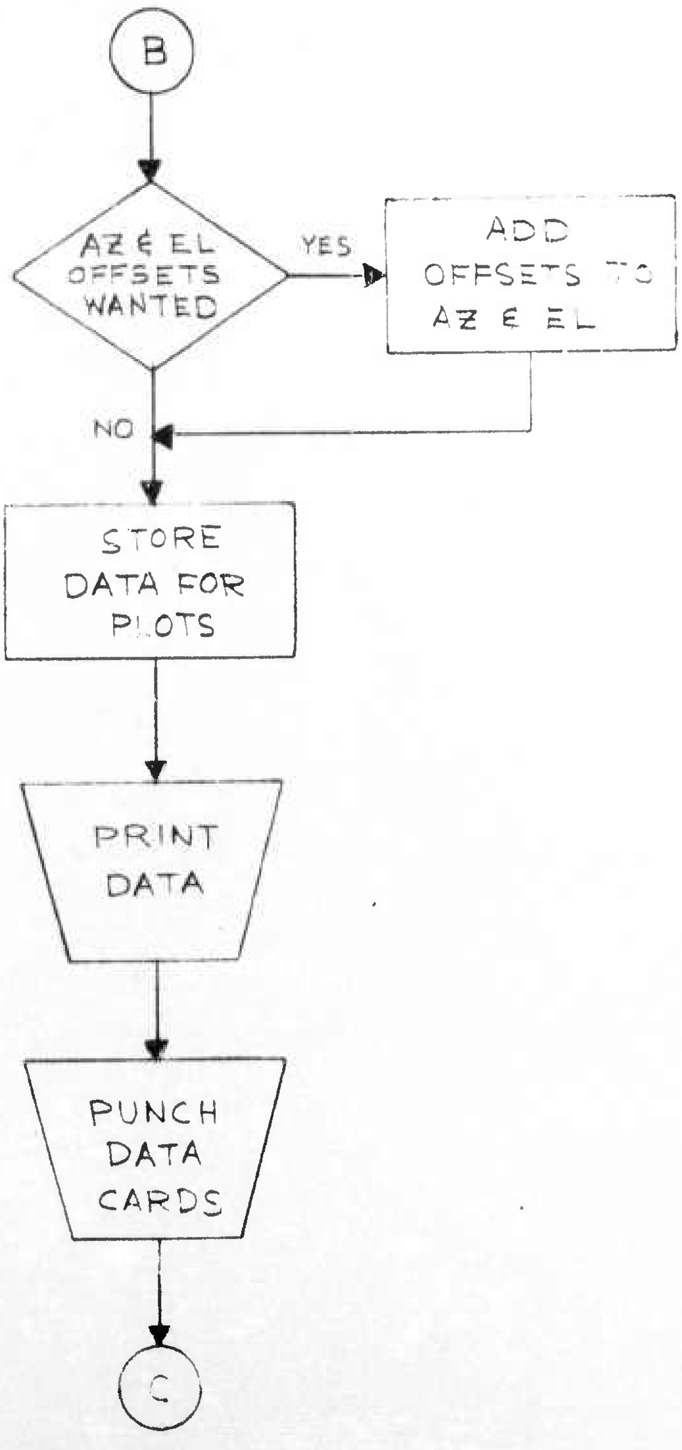
APPENDIX D

ALTPDO FLOW DIAGRAM

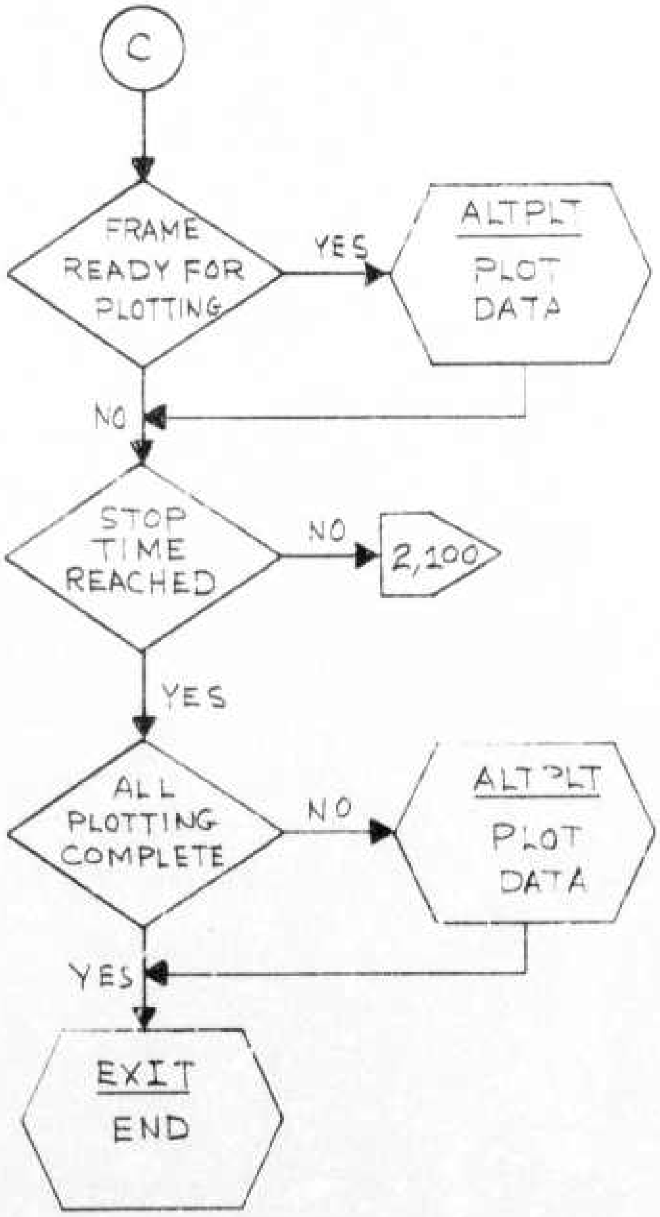


APPENDIX D-2


A
ALTP & SIGMAH BLANK
YES
SPECIFY NORMAL ALTP & SIGMAH
NO
WHDATE
DETERMINE ARTP VERSION DATE
PRINT INPUT PARAMETERS
4, 100
REA
READ & COMPUTE DATA FROM TAPE
ARTP VERSION ON OR AFTER 12 MAR 71
NO
CORRELATE AZ & EL VALUES WITH CORRECT TIMES
YES
B


B
AZ & EL
OFFSETS
WANTED
YES
ADD
OFFSETS TO
AZ & EL
NO
STORE
DATA FOR
PLOTS
PRINT
DATA
PUNCH
DATA
CARDS
C

APPENDIX D-4


C
FRAME READY FOR PLOTTING
YES
ALTPLT
PLOT DATA
NO
STOP TIME REACHED
NO
2,100
YES
ALL PLOTTING COMPLETE
NO
ALTPLT
PLOT DATA
YES
EXIT
END

APPENDIX E

SUBROUTINE BMFND PROGRAM LISTING

```
      SUBROUTINE BMFND
C     AUGUST 10, 1971
      COMMON /BM/ BMS(3,3)
      BMS(1,1) = -21.687
      BMS(1,2) = -22.937
      BMS(1,3) = -25.313
      BMS(2,1) = -27.875
      BMS(2,2) = -29.813
      BMS(2,3) = -32.500
      BMS(3,1) = -29.437
      BMS(3,2) = -31.313
      BMS(3,3) = -34.563
      RETURN
      END
```

APPENDIX F

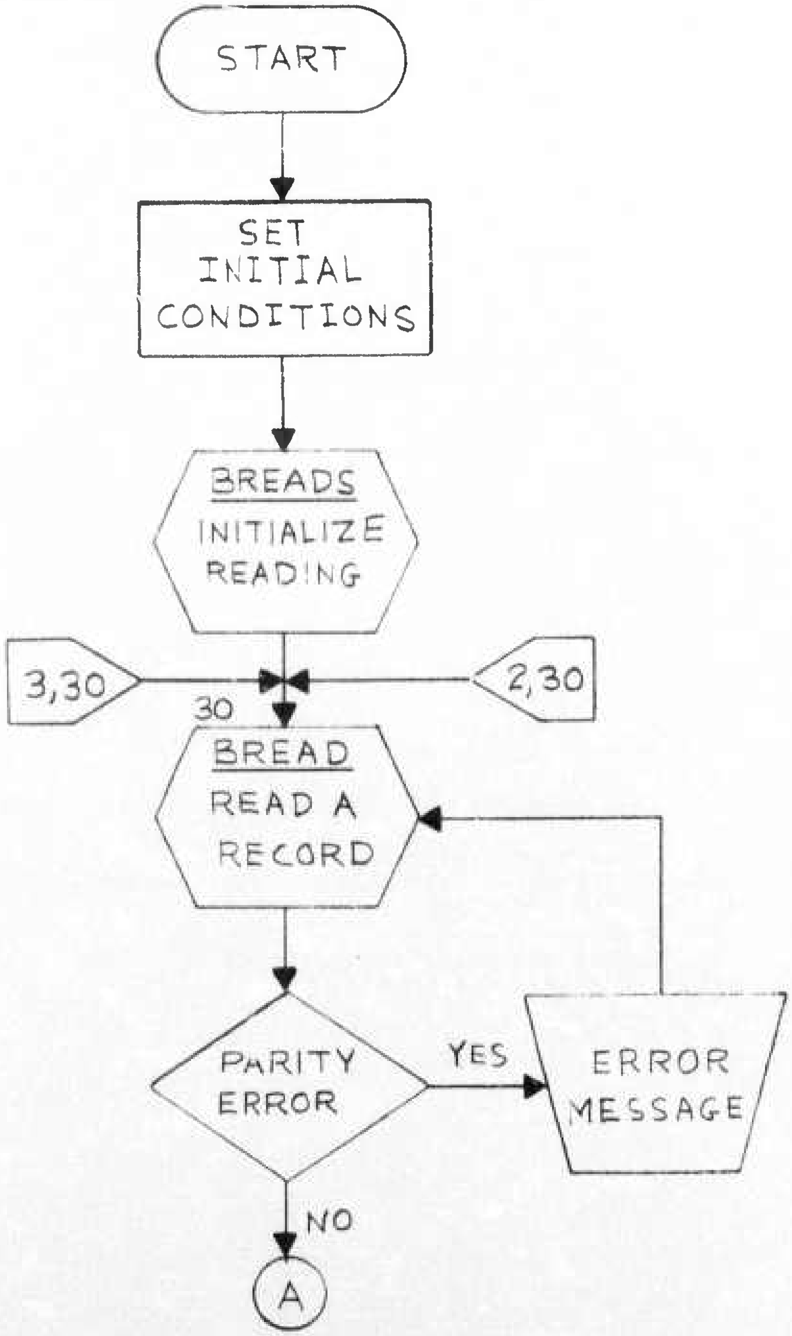
SUBPOUTINE CHEAD PROGRAM LISTING

```
      SUBROUTINE CHEAD(*)
C
C     VERSION 04/01/71     R.H. FRENCH
C
C     THIS SUBROUTINF IS USED TO PROCESS ALTAIR CATALOG TAPE OATA
C     RECOROS.
C
C     IN THIS VERSION FORMAT TABLE FMRR11 HAS BEEN AOOEO. THE IDARR
C     ARRAY HAS BEEN PUT IN COMMON SO THAT THE RTS AND ARTP VERSION
C     OATES CAN BE PRINTED OUT BY THE MAIN PROGRAM. THESE CATE(S) CAN
C     ALSO BE USED TO TRIGGER THE FLOW OF THE MAIN PROGRAM.
C
      INTEGER*2 ITEM
      INTEGER*2 IBU,IBU2
      COMMON/BEAO/LN,IFLG,IAOD,FMROIO,FMCATF,FMCSAD,FMCMDB,FMCTIB,FMCIDB
     1,FMCTOB,FMRORD,FMRORM,FMRORT,FMGLDT,FMRRO5,FMAXSP,FMBIAS,FMR5CH
     2,FMRCHF,FMAACC,FMRR11,NAME(19),NI(18),IX(18),ITEM(8000)
      COMMON/TITLE/IDARR(10)
      DIMENSION IBUF1(2048),IBUF2(2048),MCATF(18),NAMEX(19)
      EQUIVALENCE (FMROID,MCATF(1))
      EQUIVALENCE (IBUF1(1),IBU),(IBUF2(1),IBU2)
      DATA NAMEX/'ROID','CATF','CSAO','CMDB','CTIB','CIOB','CTOB','RDRD'
     1,'RDRM','RORT','GLOT','RRO5','AXSP','BIAS','R5CH','RCHF','AACC'
     2,'RR11','HDRD'/
      OATA MAX/8192/,IFL/0/,IT/1/
      NREC=0
      IN=1
      DO 20 I=1,18
      MCATF(I)=0
      NAME(I)=NAMEX(I)
      NI(I)=0
   20 IX(I)=0
      NAME(19)=NAMEX(19)
      CALL BREADS(LN,IBUF1,IBUF2,MAX,IFL,INDX,LEN,IFLG,IACC)
   30 CALL BREAD(LN)
      NREC=NREC+1
      IF(IFLG.EQ.2)GO TO 55
      IF(IFLG.EQ.3.ANO.IT.EQ.1)GO TO 30
      IF(IFLG.EQ.3)GO TO 90
      GO TO (21,22),INDX
   21 IF(IBU/256.EQ.1)GO TO 90
      GO TO 34
   22 IF(IBU2/256.EQ.1)GO TO 90
   34 CALL NAMET(IAOD,NAMED)
      IF(NAMEO.EQ.NAMEX(19))GO TO 36
      WRITE(6,85)NAMED
   85 FORMAT(1X,A4,'  FOUNO')
   36 OO 18 I=1,19
      IF(NAMED.EQ.NAMEX(I))GO TO 35
   18 CONTINUE
      GO TO 30
   35 CALL FORM(IAOO,ITEM(IT),IB,NAMEO,NTEM,&70)
      IF(NAMED.EQ.NAMEX(19))GO TO 66
      DO 40 I=1,18
      IF(NAME(I).EQ.NAMED)GO TO 60
   40 CONTINUE
```

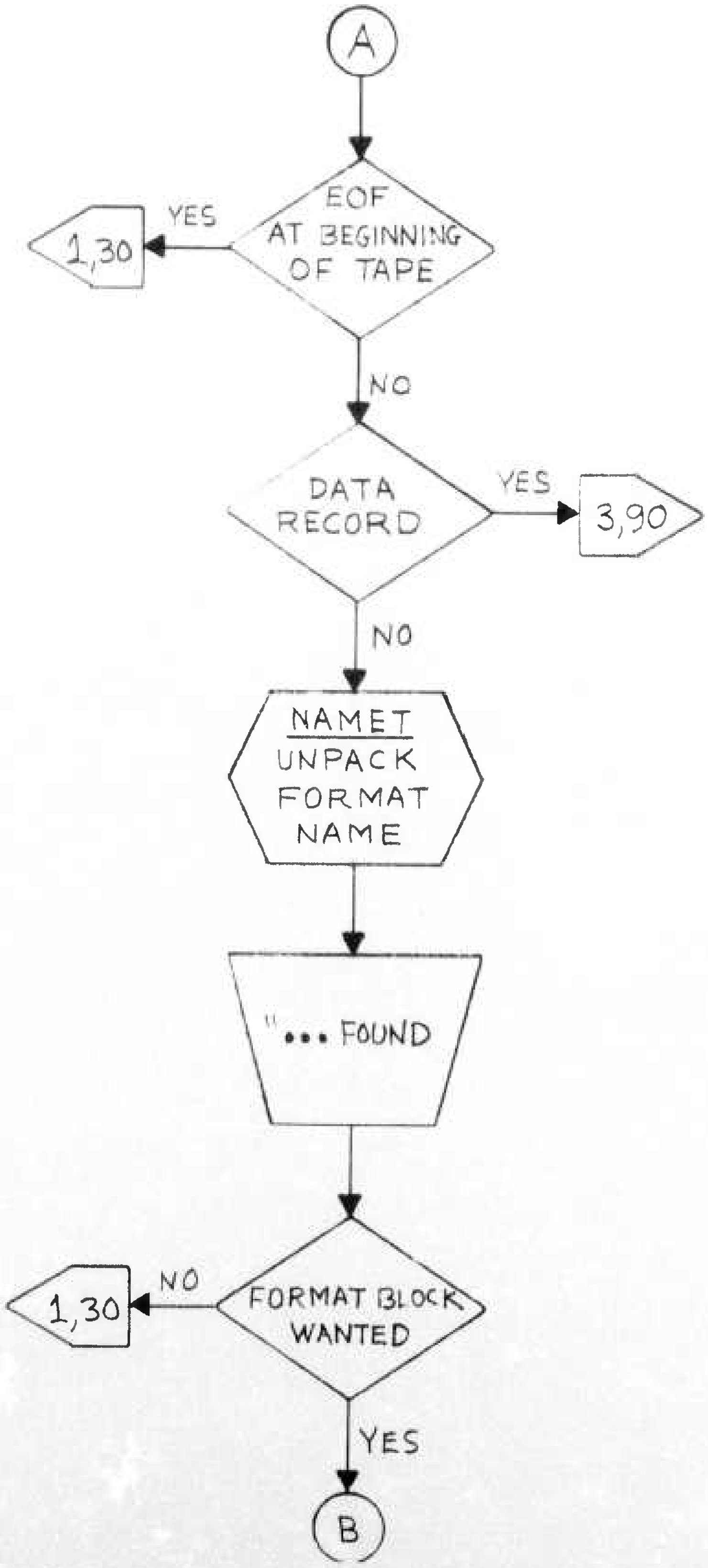
```
      GO TO 30
55    WRITE(6,56)NREC
56    FORMAT(' PARITY ERROR READING FORMAT RECORD',I6)
      GO TO 30
60    MCATF(I)=(B
      WRITE(6,9)NAMED, TEM
9     FORMAT(' FORMAT=',A4,'  STORED IN COMMON  NTEM=',I4)
      IX(I)=IT
      NI(I)=NTEM
      IT=IT+6*NTEM
      GO TO 30
66    CALL HCRR((ADD,ITYP,IDARR)
      WRITE(6,72)ITYP
72    FORMAT(' TYPE ',I2)
      IF(ITYP.EQ.1)GO TO 30
      WRITE(6,68)
68    FORMAT(' TAPE NOT CATALOG TAPE JOB TERMINATED BY CHEAD')
      RETURN 1
70    WRITE(6,80)NAMED,NTEM
80    FORMAT(' NAME = 'A4,'    NTEM ='I5,' *ERROR* FORMAT TABLE LIMITED T
     .O 700 ITEMS OR FORMAT TABLE HAS 0 LENGTH')
90    DO 81 I=1,18
      IF(MCATF(I).EQ.0)WRITE(6,82)NAMEX(I)
82    FORMAT(1X,A4,' NOT FOUND')
81    CONTINUE
      WRITE(6,150)
150   FORMAT(' CHEAD COMPLETE')
      RETURN
      END
```

APPENDIX G

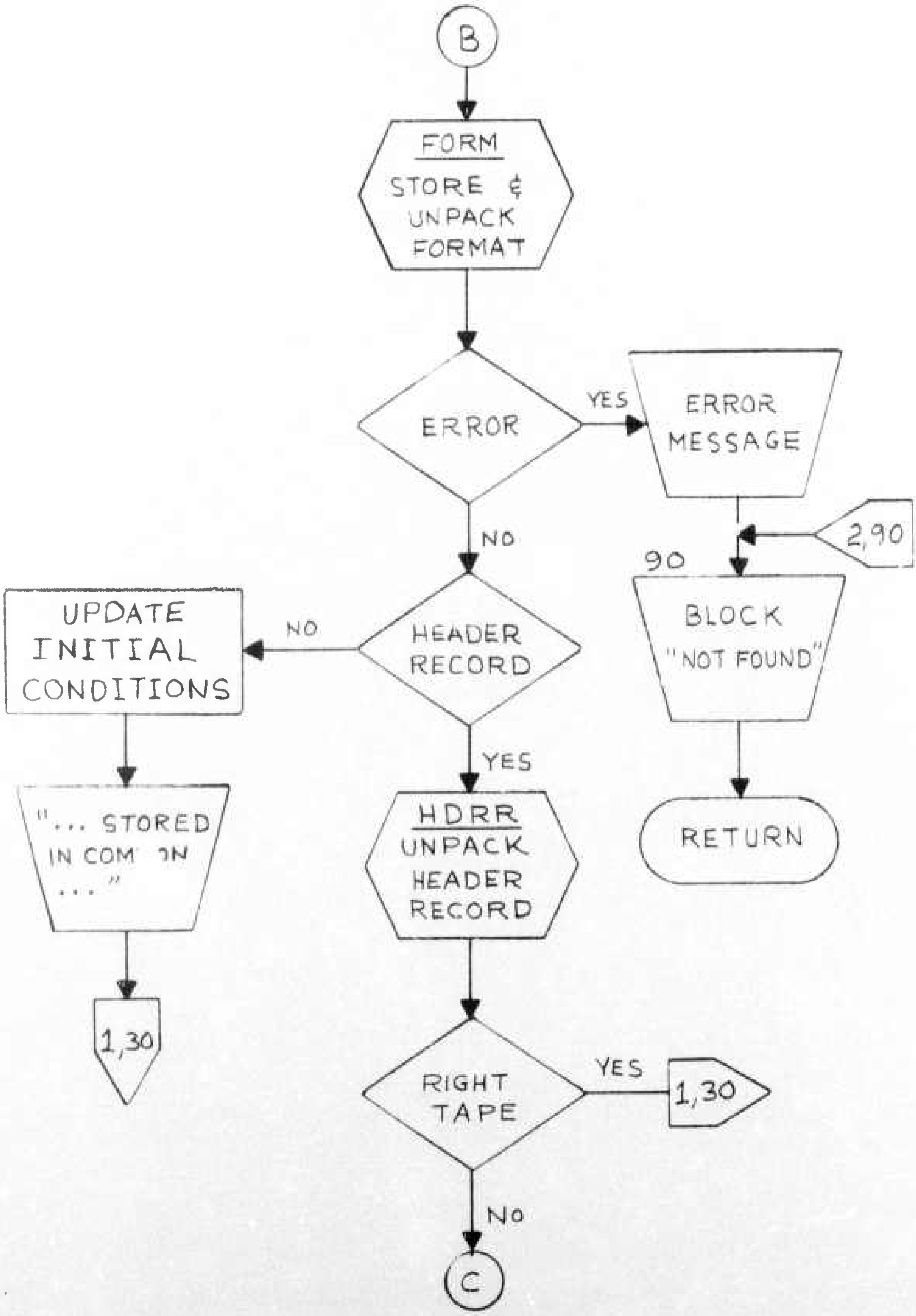
SUBROUTINE CHEAD FLOW DIAGRAM



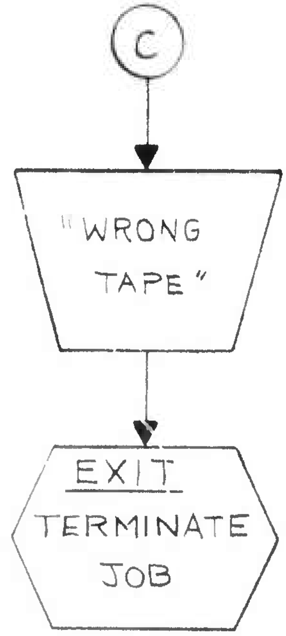
APPENDIX G-2


A
EOF
AT BEGINNING
OF TAPE
YES
1,30
NO
DATA
RECORD
YES
3,90
NO
NAMET
UNPACK
FORMAT
NAME
"... FOUND
FORMAT BLOCK
WANTED
NO
1,30
YES
B

APPENDIX G-3


B
FORM
STORE & UNPACK FORMAT
ERROR
YES
ERROR MESSAGE
NO
2,90
90
BLOCK "NOT FOUND"
RETURN
UPDATE INITIAL CONDITIONS
NO
HEADER RECORD
YES
"... STORED IN COM ON ..."
HDRR
UNPACK HEADER RECORD
1,30
RIGHT TAPE
YES
1,30
NO
C

APPENDIX G-4



APPENDIX H

SUBROUTINE CHEAD OUTPUT

```
ID=OS
TYPE  1
CSAD   FOUND
FORMAT=CSAD   STORED  IN  COMMON   NTEM=    6
CTIB   FOUND
FORMAT=CTIB   STORED  IN  COMMON   NTEM=    3
CIDB   FOUND
FORMAT=CIDB   STORED  IN  COMMON   NTEM=    5
CTDB   FOUND
FORMAT=CTDB   STORED  IN  COMMON   NTEM=    4
RDRD   FOUND
FORMAT=RDRD   STORED  IN  COMMON   NTEM=   18
RDRM   FOUND
FORMAT=RDRM   STORED  IN  COMMON   NTEM=  127
RDRT   FOUND
FORMAT=RDRT   STORED  IN  COMMON   NTEM=   10
EMSP   FOUND
PAC2   FOUND
APC3   FOUND
APC6   FOUND
PA05   FOUND
PA63   FOUND
TRHD   FOUND
TRMA   FOUND
TRTG   FOUND
TRMI   FOUND
TRSP   FOUND
RDID   FOUND
FORMAT=RDID   STORED  IN  COMMON   NTEM=    4
AACC   FOUND
FORMAT=AACC   STORED  IN  COMMON   NTEM=    8
AMP1   FOUND
AMP2   FOUND
AMP3   FOUND
AMP4   FOUND
AMP5   FOUND
AMP6   FOUND
APC1   FOUND
ASLP   FOUND
ASMP   FOUND
ATRK   FOUND
AXSP   FOUND
FORMAT=AXSP   STORED  IN  COMMON   NTEM=   29
BCAL   FOUND
BIAS   FOUND
FORMAT=BIAS   STORED  IN  COMMON   NTEM=   19
BSMC   FOUND
CATF   FOUND
FORMAT=CATF   STORED  IN  COMMON   NTEM=   23
CHAF   FOUND
CMDB   FOUND
FORMAT=CMDB   STORED  IN  COMMON   NTEM=   51
GLOT   FOUND
FORMAT=GLOT   STORED  IN  COMMON   NTEM=    7
NOM1   FOUND
NOM2   FOUND
NOM3   FOUND
NOM4   FOUND
OBJT   FOUND
PHA1   FOUND
PHA2   FOUND
PHA3   FOUND
PHA4   FOUND
PHA5   FOUND
PHA6   FOUND
RCHF   FOUND
FORMAT=RCHF   STORED  IN  COMMON   NTEM=    6
R4CH   FOUND
R5CH   FOUND
FORMAT=R5CH   STORED  IN  COMMON   NTEM=   32
RR04   FOUND
RR05   FOUND
FORMAT=RR05   STORED  IN  COMMON   NTEM=    8
RR06   FOUND
RR07   FOUND
RR08   FOUND
RR09   FOUND
ERRO   FOUND
SCAN   FOUND
XSEC   FOUND
DRG1   FOUND
DRG2   FOUND
DRG3   FOUND
SASD   FOUND
RR11 NOT FOUND
CHEAD COMPLETE
```

APPENDIX J
SUBROUTINE WHDATE PROGRAM LISTING

```
WHDATE   START 0
         USING *,15
         STM   14,12,12(13)
         LM    7,9,0(1)
         L     2,0(7)
         L     3,0(8)
         LR    4,3
         SRDL  4,24
         SRL   5,16
         C     5,=X'0000F7F1'
         BL    OLD
         BH    NEW
         SRDL  4,8
         LR    4,2
         SRDL  4,16
         SRL   5,8
         A     5,=X'40000000'
         LA    6,TABLE
         LA    7,0
TEST     C     5,0(7,6)
         BE    LOOK
         A     7,=F'4'
         B     TEST
LOOK     C     7,=F'8'
         BE    T11
         BL    OLD
NEW      L     3,=F'1'
RET      ST    3,0(9)
         LM    14,12,12(13)
         BR    14
OLD      LA    3,2
         B     RET
T11      SRL   2,16
         C     2,=X'0000F1F1'
         BL    OLD
         B     NEW
         CNOP  0,8
TABLE    DC    CL4' JAN'
         DC    CL4' FEB'
         DC    CL4' MAR'
         DC    CL4' APR'
         DC    CL4' MAY'
         DC    CL4' JUN'
         DC    CL4' JUL'
         DC    CL4' AUG'
         DC    CL4' SEP'
         DC    CL4' OCT'
         DC    CL4' NOV'
         DC    CL4' DEC'
         LTORG
         END
```

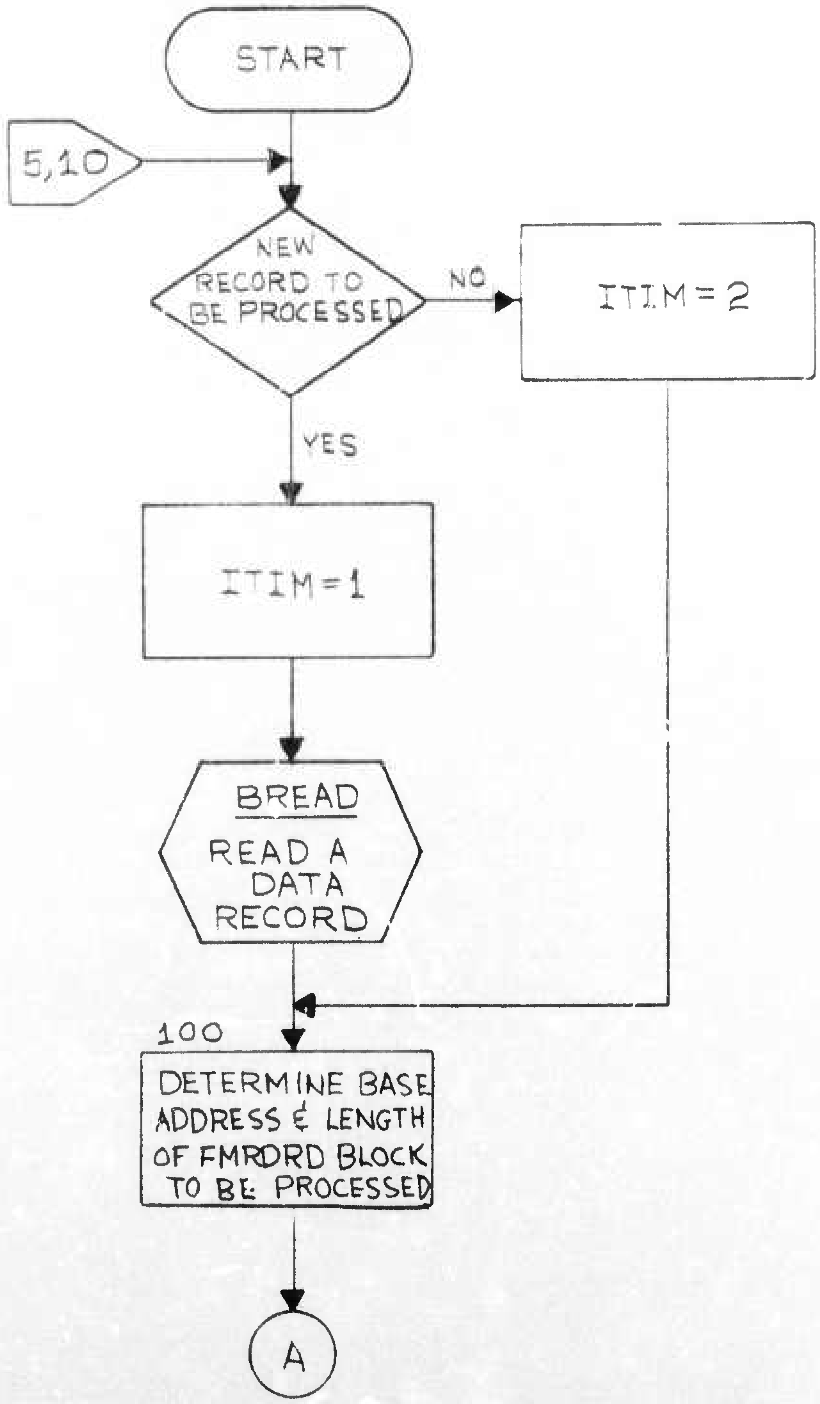
APPENDIX K
SUBROUTINE REA PROGRAM LISTING

```
      SUBROUTINE REA(DTIME,ICC,IONC)
C   AUGUST 10, 1971
      REAL * 8 START,STOP,RNG2,OTIME,DINT,XX,GMT
      INTEGER*2 ITEM
      COMMON /DRMOTA/GMT,RNG2,R,E,A,DF,F18,F19,F20,N23
      COMMON /SDATA/SNDB,OTHETA,ORANG
      COMMON /IOCORS/RCIO,ELCIO,ALTP,SIGH
C     COMMON/BEAD/LN,IFLG,IADD,FMRDIO,FMCATF,FMCSAO,FMCMDB,FMCTIB,FMCIDB
C    1,FMCTOB,FMRORD,FMRORM,FMRORT,FMGLOT,FMRR05,FMRR06,FMRR11,FMR5CH
C    2,FMAP01,FMAP03,FMRCHF,FMAACC,NAME(20),NI(19),IX(19),ITEM(8000)
      COMMON/BEAD/LN,IFLG,IADD,FMRDIO,FMCATF,FMCSAO,FMCMDB,FMCTIB,FMCIOB
     1,FMCIDB,FMRDRO,FMRDRM,FMRDRT,FMGLOT,FMRRD5,FMAXSP,FMBIAS,FMR5CH
     2,FMRCHF,FMAACC,FMRR11,NAME(19),NI(18),IX(18),ITEM(8000)
      COMMON /BM/BMS(3,3)
      COMMON /KTAPE/NEW
      DIMENSION IBUF1(2048),IBUF2(2048),MCATF(70),NAMEX(70),BMC(5)
      INTEGER*2 IBU
      EQUIVALENCE (FMRDIO,MCATF(1)),(IBUF1(1),IBU)
      DATA NAMEX/'ROIO','CATF','CSAO','CMDB','CTIB','CIDB','CTDB','RORD'
     1,'RORM','RORT','FMS?','AP01','PA02','AP03','PA05','PA63'
     2,'TRHD','TRMA','TRI?','TRMI','TRSP'/
      DATA SLAP/1.0811/
      DATA BMC/-1946.8,-3893.7,-7787.4,-15575.0,-31149.0/
      DATA ITIM/1/
      ICAT(IML) = IGET(FMCATF,IADD,IML)
      RORM(IML) = GET(FMRORM,IBASM,IML)
      IORM(IML) = IGET(FMRORM,IBASM,IML)
      F18 = 0.
      F19 = 0.
      F20 = 0.
      N23 = 0
      GO TO (10,100),ITIM
10    CALL BREAD(LN)
      ICC = ICC + 1
      IF(IFLG.EQ.1) GO TO 66
      GO TO 10
66    ITSI = 1
      ITSJ = 1
      N50 = ICAT(12)
      L50= ICAT(13) * 3
      IBASE = ICAT(19) * 3 + IADD
C     IBASE = IBASE+(IGET(FMRORD,IBASE,1)-1)*3
100   DO 104 I = ITSI,N50
      LORM = IBASE + (I-1) * L50
      DO 103 J = ITSJ,2
      IBASM = LORM + (J-1) * 120
      IW1 = IORM(1)
      IW2 = IORM(2)
      CALL HMS(IW1,IW2,IH,IM,IS,IT)
      IF(DTIME.LE.0.0) OTIME = (IH*3600+IM*60+IS+FLOAT(IT)*.001)
      KL = DTIME
      KP = IH*3600 + IM*60 + IS
      GMT = KP + FLOAT(IT) * 0.10-02
      IF(KP.LT.KL) GO TO 103
      IF(GMT.LT.DTIME) GO TO 103
      ITIM = 2
      R = RORM(10)
      ACOR = 0.0
      ECOR = 0.0
      IF(NEW.EQ.2) ACOR = GET(FMAACC,IADD,3) * 57.29578
      IF(NEW.EQ.2) ECOR = GET(FMAACC,IADD,5) * 57.29578
      A = RORM(13) * 360.0 + ACOR
      E = RORM(14) * 360.0 + ECOR
      COSEL = 1.0/COS(E/57.29578)
      F9 = IORM(9)
      ICHAFF = IORM(108)
      IF(ICHAFF.EQ.1) GO TO 21
      F18 = RORM(18)
      F19 = RORM(19)
      F20 = RORM(20)
```

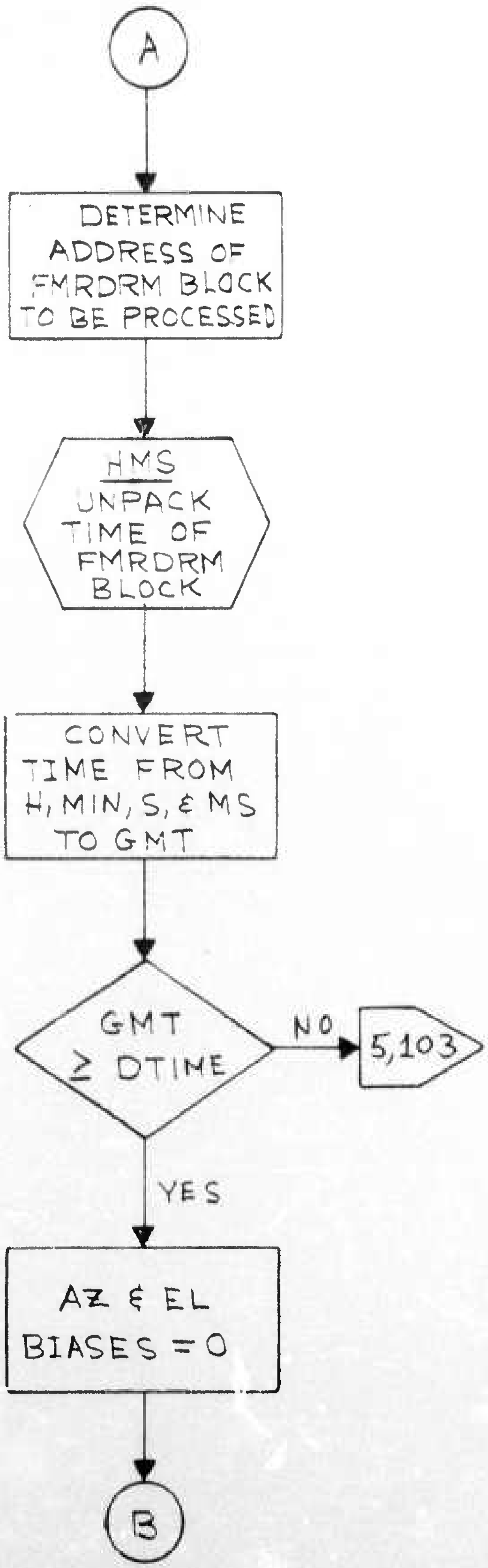
```
      N23 = IDRM(23)
      IF(N23.EQ.0) GO TO 27
      IT28 = IORM(28)
      IT61 = IDRM(61)
      IF(IT28.GT.4.OR.IT61.GT.4) GO TO 20
      IF(IT61.EQ.4) IT61 = 3
      IF(IT28.EQ.4) IT28 = 3
      BTHING = BMS(IT28,IT61) * .9144
      F18 = (F18/N23) * BTHING
20    X4 = GET(FMRR05,IADD,4)
      X2 = GET(FMRR05,IADD,2)
      CALL BZERO(X4)
      CALL BZERO(X2)
      F19 = (F19/N23) * (.057/X2) * COSEL
      F20 = (F20/N23) * (.057/X4)
      GO TO 27
21    ITTM = IDRM(107)
      USEBM = BMC(ITTM)
      F98 = IDRM(98)
      F104 = IORM(104)
      IF(F104.EQ.0.0) GO TO 27
      F18 = (F98/F104) * USEBM * .9144
      F99 = IDRM(99)
      F100 = IDRM(100)
      I107 = IORM(107)
      IA = I107 + 1
      IE = I107 + I1
      XA = GET(FMR5CH,IADD,IA)
      XE = GET(FMR5CH,IADD,IE)
      XA = BZERO(XA)
      XE = BZERO(XE)
      F19 = (F99/F104) * (.057/XA) * COSEL
C     F19 = (F99/F104) * (0.057/0.053) * COSEL
      F20 = (F100/F104) * (.057 / XE)
C     F20 = (F100/F104) * (.057 /.053)
27    F85 = IORM(85)
      F86 = RDRM(86)
      RNG2 = (F85+F86) * 3.0
      RCID = 0.0
      ELCID = 0.0
      IF(IDNC.EQ.0) GO TO 62
      OTR = RORM(75) * 3.0
      RCID = OTR * 1.166 * .3048E-03
      OTR = OTR * .3048E-03
      RKM = RNG2 * .30480-03
      EEE = E
      CALL IDNCDR(ALTP,SIGH,RKM,EEE,OTR,ELCIC)
62    COR = 0.0
      IF(NEW.EQ.2) COR = IGET(FMRR11,IADD,3) * 1.87371 / .3048
      F = RNG2 + CDR
      CALL REFC(E,F,DE,DF)
      RNG2 = ((RNG2 + CDR - DF) * .30480-03) - RCID
      E = E - DE - ELCID
      SNDB = 0.0
      DTHETA = 0.0
      ORANG = 0.0
      IDIGT = IDRM(26)
      LALL = IDRM(25)
      CALL HM25(LALL,IHMCH)
      SNDB=2.2+IDIDT*3-10*IORM(51) + IHMCH
      PRF = 1.0 / (ICAT(5) * 1.0E-06)
      SN = 10.0 ** (SNDB/10.0)
      SS = SQRT(SN * 0.025 * PRF)
      DTHETA = (40.0/SS) * 0.05729578
      ORANG= 21.75/SS
277   ITSJ = ITSJ + 1
      IF(J.GE.2) GO TO 101
      GO TO 102
101   ITSI = ITSI + 1
      ITSJ = 1
      IF(ITSI.GT.N50) ITIM = 1
102   RETURN
103   CONTINUE
104   CONTINUE
      GO TO 10
      END
```

APPENDIX L

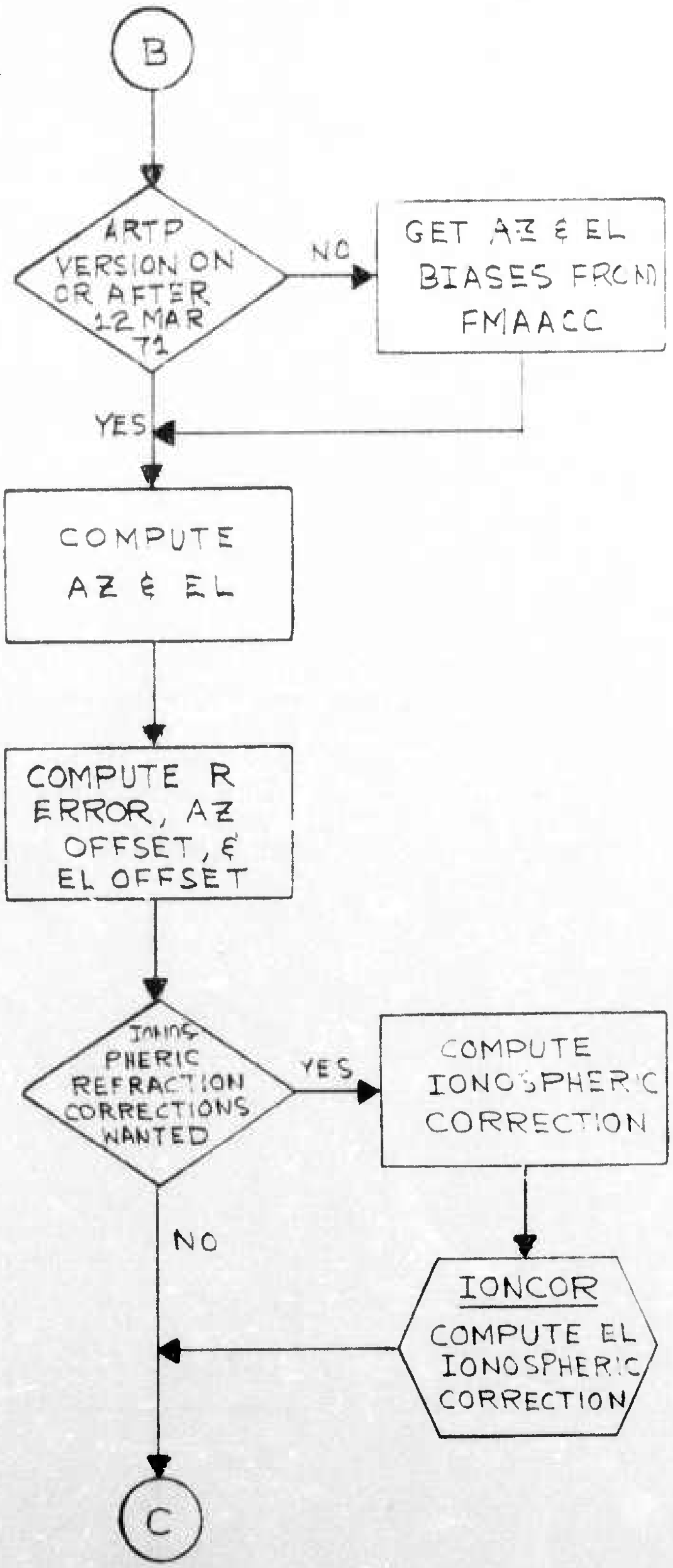
SUBROUTINE REA FLOW DIAGRAM



APPENDIX L-2

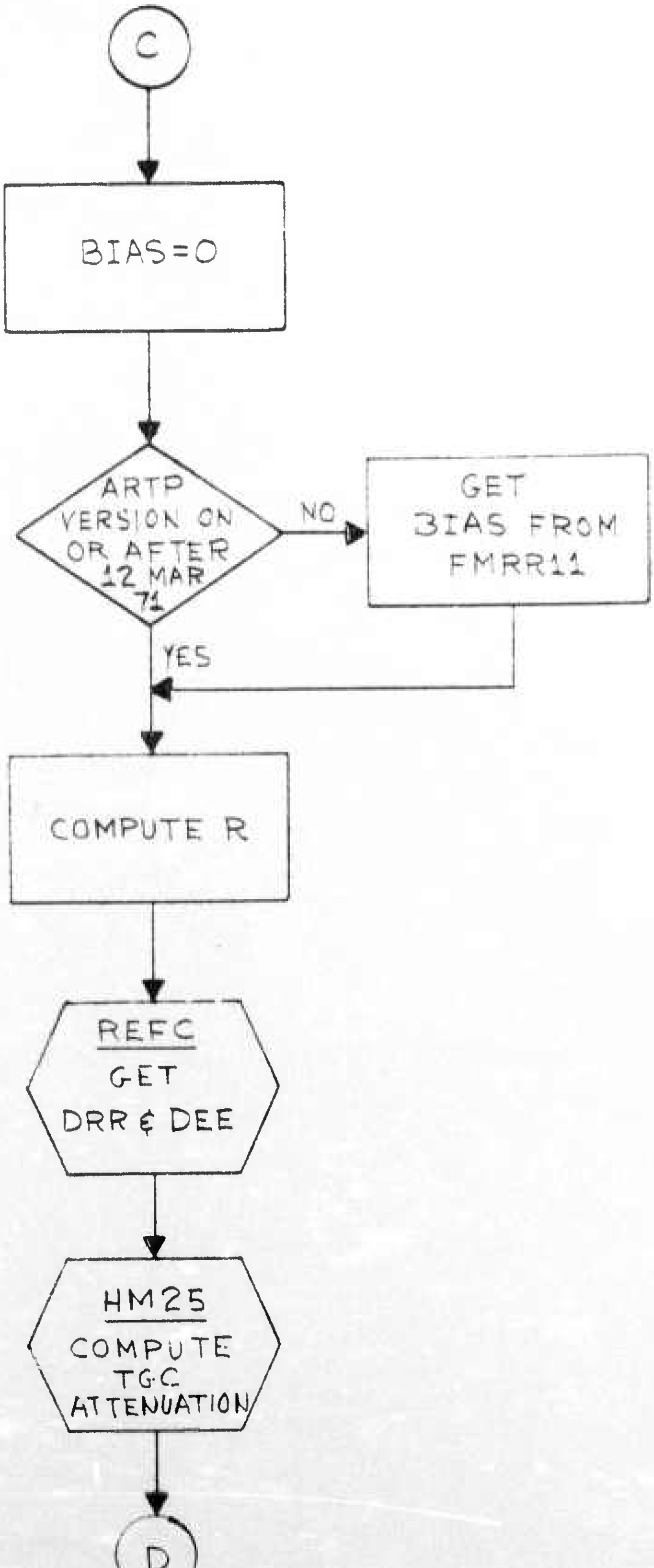

A
DETERMINE ADDRESS OF FMRDRM BLOCK TO BE PROCESSED
HMS
UNPACK TIME OF FMRDRM BLOCK
CONVERT TIME FROM H, MIN, S, & MS TO GMT
GMT ≥ DTIME
NO
5,103
YES
AZ & EL BIASES = 0
B

APPENDIX L-3

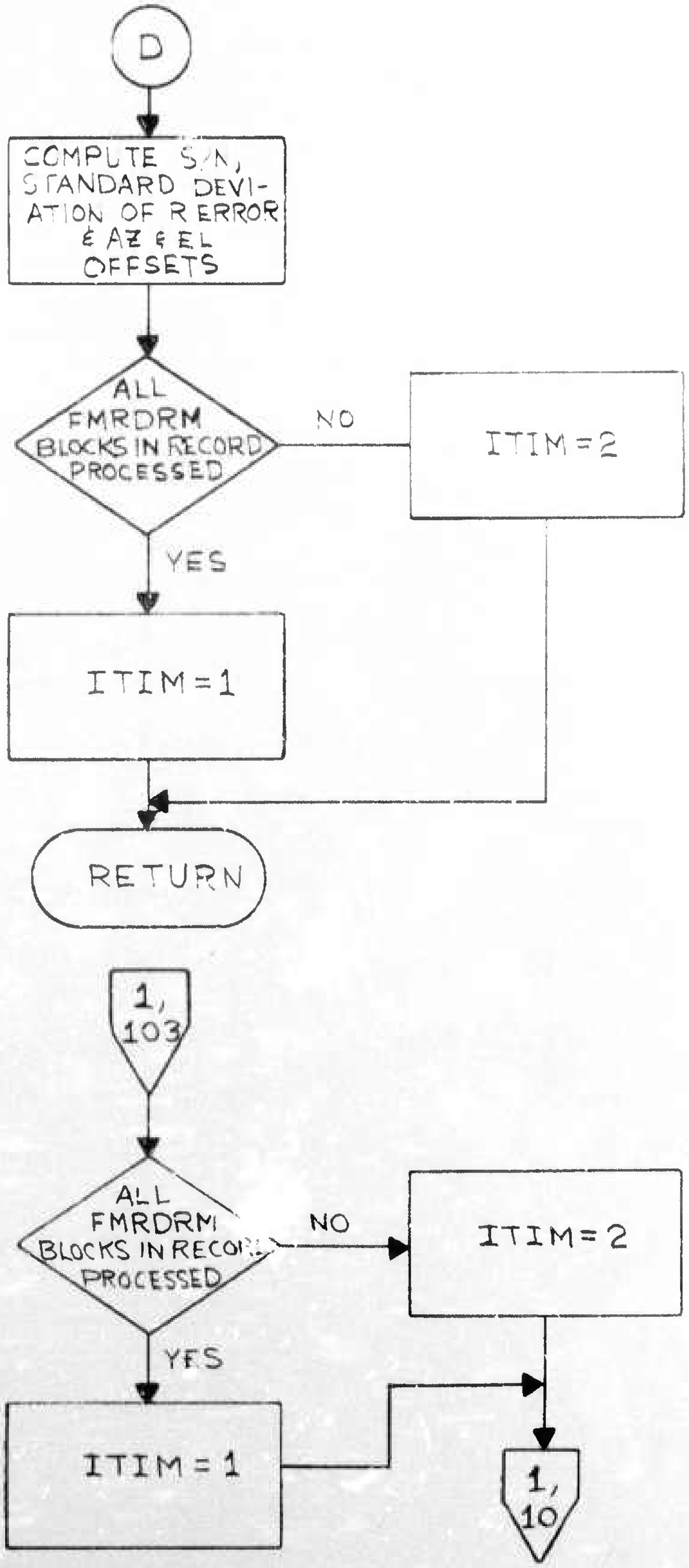


B
ARTP VERSION ON OR AFTER 12 MAR 71
NO
GET AZ & EL BIASES FROM FMAACC
YES
COMPUTE AZ & EL
COMPUTE R ERROR, AZ OFFSET, & EL OFFSET
IONOSPHERIC REFRACTION CORRECTIONS WANTED
YES
COMPUTE IONOSPHERIC CORRECTION
NO
IONCOR
COMPUTE EL IONOSPHERIC CORRECTION
C

APPENDIX L-4


C
BIAS=O
ARTP VERSION ON OR AFTER 12 MAR 71
NO
GET BIAS FROM FMRR11
YES
COMPUTE R
REFC
GET DRR & DEE
HM25
COMPUTE TGC ATTENUATION
D

APPENDIX L-5


D
COMPUTE S/N, STANDARD DEVIATION OF R ERROR & AZ & EL OFFSETS
ALL FMRDRM BLOCKS IN RECORD PROCESSED
NO
ITIM=2
YES
ITIM=1
RETURN
1, 103
ALL FMRDRM BLOCKS IN RECORD PROCESSED
NO
ITIM=2
YES
ITIM=1
1, 10

APPENDIX M

SUBROUTINE HMS PROGRAM LISTING

```
SUBROUTINE HMS(IW1,IW2,IH,IM,IS,IT)
MU = MOD(IW1,16)
MT = MOD((IW1/16),8)
IM = MT * 10 + MU
IHU = MOD((IW1/256),16)
IHT = MOD((IW1/4096),4)
IH = IHT * 10 + IHU
ITTH = MOD(IW2,16)
ITHU = MOD((IW2/16),16)
ITTN = MOD((IW2/256),16)
IT = ITTH + ITHU * 10 + ITTN * 100
ISU = MOD((IW2/4096),16)
IST = MOD((IW2/65536),8)
IS = ISU + IST * 10
RETURN
END
```

APPENDIX N

SUBROUTINE HM25 PROGRAM LISTING

```
      SUBROUTINE HM25(LALL,IHMCH)
      DIMENSION K(5)
      IHMCH = 0
      IALL = LALL
      DO 3 I = 1,[illegible]
      K(I) = 0
      K(I) = MOD(IALL,2)
      IALL = IALL/10
3     CONTINUE
      IF(K(1).EQ.1) K(1) = 3
      IF(K(2).EQ.1) K(2) = 3
      IF(K(3).EQ.1) K(3) = 6
      IF(K(4).EQ.1) K(4) = 12
      IF(K(5).EQ.1) K(5) = 24
      IHMCH = K(1)+K(2)+K(3)+K(4)+K(5)
      END
```

APPENDIX O

SUBROUTINE BZERO PROGRAM LISTING

```
         START 0        VERSION: 7/29/70
         ENTRY BZERO
         USING *,15
BZERO    B     H5
         DC    X'05',CL5'BZERO'
H5       STM   14,12,12(13)
         L     6,0(1)
         MVC   WORD,0(6)
         LE    4,WORD
         LPER  6,4
         CE    6,=E'1.'
         BL    H20
         AU    4,X6
         STE   4,WORD
         L     7,WORD
         SR    9,9
         LTR   7,7
         SLL   7,8
         BNL   H10
         LA    9,1
H10      SRL   7,8
         SR    2,2
         AH    2,=X'0103'
         SRDL  2,2
         SRL   3,30
         SLL   7,0(3)
         SRL   7,2
         SRDL  2,8
         OR    7,3
         SLL   9,31
         OR    7,9
         SER   2,2
         ST    7,WORD
         AE    2,WORD
         STE   2,WORD
         MVC   0(4,6),WORD
H20      RETURN (14,12)
WORD     DS    1E
X6       DC    X'46000000'
         END
```

APPENDIX P

SUBROUTINE IONCOR PROGRAM LISTING

```
      SUBROUTINE IONCOR(ALTP,SIGMAH,RANGE,ELEV,DELTAR,DELTAE)
C     ALTP=ALTITUDE OF PEAK ELECTRON DENSITY (INPUT IN KM)
C     SIGMAH=WIDTH OF THE IONOSPHERE (INPUT IN KM)
C     RANGE=RANGE FOR EACH REQUESTED POINT FROM MAIN PROGRAM (INPUT IN K
C     ELEV=ELEVATION FOR EACH REQUESTED POINT FROM MAIN PROGRAM
C    1(INPUT IN DEGRRES)
C     DELTAR=RDRM(75) /1093.611
C     ELCOR=CORRECTED EVELVATION ANGLE FOR EACH REQUESTED POINT (OUTPUT
C    1IN DEGREES)
      ELEV=ELEV/57.29578
      ERAD=6378.145                                  VERSION: 5/13/71
      SINEL=SIN(ELEV)
      BETA =RANGE/(ERAD*SINEL)
      C = 1+(ALTP*(2*ERAD+ALTP))/((ERAD*SINEL)**2)
      SQRTC=SQRT(C)
      UP=(SQRTC-1)/BETA
      SIGMA=SIGMAH/(RANGE*SINEL*(1+BETA*UP*(COS(ELEV)**2)))
      A=(1-UP)/SIGMA
      Z=1+((BETA*SIGMA)/(1+BETA*UP))*(EXP(-(A*A))/(.8862269*(1+ERF(A))))
      DELTAE=(COTAN(ELEV)*(DELTAR/RANGE)*((1+BETA)/C))*Z
      DELTAE=DELTAE*57.29578
      RETURN
      END
```

APPENDIX Q

SUBROUTINE REFC PROGRAM LISTING

```
      SUBROUTINE REFC(E,R,DEE,ORR)
      OIMENSION DE(16,8),DR(16,8),ED(16),RD(8)      VERSION: 6/16/70
      DATA DE/0.0   ,0.0   ,0.0   ,0.0   ,0.0   ,0.0   ,0.0   ,0.0   ,
     10.0   ,0.0   ,0.0   ,0.0   ,0.0   ,0.0   ,0.0   ,0.0   ,0.0313,
     20.0303,0.0292,0.0287,0.0282,0.0272,0.0262,0.0253,0.0243,0.0223,
     30.0214,0.0195,0.0171,0.0135,0.0075,0.0   ,0.0937,0.0848,0.0770,
     40.0732,0.0694,0.0627,0.0571,0.0522,0.0480,0.0412,0.0385,0.0337,
     50.0278,0.0205,0.0105,0.0   ,0.1850,0.1520,0.1250,0.114C,0.1050,
     60.0904,0.0795,0.0708,0.0636,0.0523,0.0478,0.0405,0.0323,0.0229,
     70.0114,0.0   ,0.5310,0.3070,0.2120,0.1830,0.1600,0.1280,0.1060,
     80.0899,0.0780,0.0612,0.0550,0.0455,0.0354,0.0246,0.0120,0.0   ,
     90.7550,0.3720,0.2400,0.2020,0.1750,0.1370,0.1120,0.0942,0.0811,
     A0.0631,0.0566,0.0466,0.0361,0.0250,0.0122,0.0   ,0.9120,0.4110,
     80.2560,0.214C,0.1840,0.1420,0.1150,0.0967,0.0830,0.0643,0.0575,
     C0.0472,0.0365,0.0252,0.0122,0.0   ,0.9700,0.4200,0.260C,0.2200,
     00.1900,0.1460,0.1170,0.0980,0.0840,0.0653,0.0584,0.0478,0.0369,
     E0.0254,0.0123,0.0 /
      DATA OR/  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
     1  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  C.0, 22.6, 21.5, 20.4, 19.9,
     2 19.4, 18.5, 17.6, 16.8, 16.1, 14.8, 14.2, 13.2, 12.0, 10.4,  8.6,
     3  7.7, 67.3, 57.9, 50.2, 47.0, 44.1, 39.3, 35.4, 32.1, 29.3, 24.8,
     4 22.9, 19.7, 16.3, 12.7,  9.4,  8.1,132.0, 98.5, 77.4, 69.7, 63.2,
     5 52.9, 44.7, 38.4, 33.4, 26.4, 23.9, 20.1, 16.4, 12.7,  9.4,  8.1,
     6340.0,167.0,103.0, 86.1, 73.4, 56.7, 46.2, 38.9, 33.6, 26.4, 24.0,
     7 20.2, 16.4, 12.8,  9.5,  8.2,405.0,17C.0,104.0, 86.3, 73.6, 56.8,
     8 46.3, 38.9, 33.7, 26.5, 24.1, 20.3, 16.5, 12.8,  9.5,  8.2,421.0,
     9171.0,104.0, 86.6, 73.9, 57.1, 46.4, 39.0, 33.8, 26.8, 24.3, 20.5,
     A 16.6, 13.0,  9.8,  8.4,446.0,172.0,105.0, 87.4, 74.0, 58.0, 46.6,
     8 39.2, 34.0, 27.0, 24.6, 20.7, 16.7, 13.0, 10.0,  8.4/
      DATA ED,RTDEG/0.01,2.0,4.0,5.0,6.0,8.0,10.0,12.0,14.0,18.,20.,
     124.,30.,40.,60.,90.,57.29578/
      OATA RD/0.01,10.,30.,60.,200.,400.,1000.,2000./
      IF(R.LE.0.0)GO TO 300
      RG=R/6080.27
      OO 100 IED=2,15
      I=17-IED
      IF(E.GE.ED(I))GO TO 120
  100 CCNTINUE
      I=1
  120 DO 200 JRD=2,8
      J=10-JRD
      IF(RG.GE.RD(J))GO TO 220
  200 CCNTINUE
      J=1
  220 IF(J.EQ.8)GO TO 340
      ZR=ALOG(RG/RD(J))/ALOG(RD(J+1)/RD(J))
      IF(E.LE.0.0)GO TC 320
      ZE=ALOG(E/ED(I))/ALOG(ED(I+1)/ED(I))
      DE1=((DE(I+1,J)-DE(I,J))*(1.-ZR)+(DE(I,J+1)-DE(I,J))*ZR)*ZE
      DE2=((DE(I,J+1)-DE(I,J))*(1.-ZE)+(DE(I+1,J+1)-DE(I,J+1))*ZE)*ZR
      DEE=DE1+DE2+DE(I,J)
      OR1=((OR(I+1,J)-DR(I,J))*(1.-ZR)+(DR(I,J+1)-OR(I,J))*ZR)*ZE
      DR2=((OR(I,J+1)-OR(I,J))*(1.-ZE)+(DR(I+1,J+1)-DR(I,J+1))*ZE)*ZR
      DRR=(DR1+DR2+DR(I,J))
      GO TO 400
  300 DEE=0.0
      ORR=0.0
      GO TO 400
  320 DEE=DE(I,J)+(DE(I,J+1)-DE(I,J))*ZR
      DRR=DR(I,J)+(DR(I,J+1)-DR(I,J))*ZR
      GO TO 400
  340 DELT=(E-ED(I))/(ED(I+1)-ED(I))
      OEE=DELT*(DE(I+1,J)-DE(I,J))+OE(I,J)
      ORR=DELT*(DR(I+1,J)-OR(I,J))+DR(I,J)
  400 RETURN
      END
```